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MY AND PHYSIOLOGY
OR NURSES

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ANATOMY AND PHYSIOLOGY FOR NURSES

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PHYSICS AND CHEMISTRY FOR NURSES

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ASISTENCIA PRACTICA DE ENFERMOS

(Spanish Edition of Practical Nursing)

CON LA COOPERACION DE ANNA CAROLINE MAXWELL

Text-Book
of
Anatomy and Physiology
For Nurses

By

Amy E. Pope

Formerly Instructor in the School of Nursing, Presbyterian Hospital; Instructor in School of Nursing, St. Luke's Hospital, San Francisco, Cal. Author of "A Medical Dictionary for Nurses," "A Quiz Book of Nursing," "Essentials of Dietetics," and, with Anna Maxwell, of "Practical Nursing"

With 135 Illustrations

Third Edition, Revised and Enlarged

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PREFACE TO SECOND EDITION

THE material of the first edition of *Anatomy and Physiology for Nurses* has been thoroughly revised for this new edition and a number of questions for each chapter have been inserted at the end of the book. My thanks are due to Dr. F. G. Inman, of San Francisco, for helping me with the revision.

AMY ELIZABETH POPE.

PREFACE

If nurses are to render intelligent and interested assistance in the research work that is becoming an ever increasingly large item of hospital routine, and to do the teaching of hygiene and sanitation expected of them in connection with social-service work, it is necessary that they be well grounded in the principles of physiology. In the hope of helping in this instruction, I have sought to collect from the latest authorities on physiology the facts relating to this subject that seemed to me to be of importance for nurses to know, and to put these facts into as concise and simple language as possible.

In order not to make the book too large, I have omitted some of the details of anatomy given in many of the text-books of anatomy and physiology for nurses, but nothing, I think, that it is of importance for nurses to remember or that it is necessary for them to know in order to understand the functioning of the body.

My thanks are due to the W. B. Saunders Company for their courtesy in allowing me to use illustrations and to quote from *A Text-Book of Physiology* by William H. Howell, Ph.D., M.D.; to William Wood & Company for allowing me to

use illustrations and quote from Kirk's *Handbook of Physiology;* and to Lea & Febiger for allowing me to do the same from *A Text-Book of Anatomy by American Authors*, edited by Frederic Henry Gerrish, M.D.

AMY ELIZABETH POPE.

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Text-Book
of
Anatomy and Physiology
For Nurses

Text-Book of Anatomy and Physiology

CHAPTER I

NATURE OF THE COMPOSITION OF THE BODY

The Principal Branches Relating to the Study of the Structure and Functioning of the Body. Relation of Chemistry and Physics to Physiology. Nature of the Phenomena of Life. Chemical Composition of the Animal Body. Nature of Proteins, Carbohydrates, Fats. Inorganic Constituents of the Body. Nature of Plant and Animal Cells. Unicellular Animals and Plants. Cell Division. Life-Cycle of Cells. Difference in Cells.

1. The chemical nature and the life processes of man, the lower animals, and plants are much more similar than might be expected from their outward appearance, and much of the knowledge of the structure and functioning of the human body has been obtained from the study of the so-called *lower forms of life*. For these reasons the names of many of the branches into which such study has been divided are similar for both plants and animals, including the human animal, as can be seen by the following names and definitions:

2. BIOLOGY[1] is the science which treats of life and all living things. Two of its primary divisions are Zoölogy,[2] the science treating of animal life, and Botany,[3] the science treating of plant life. Important subdivisions of these sciences are Anatomy,[4] Physiology,[5] Embryology,[6] and Histology.[7]

3. ANATOMY, literally, means the act or process of dissecting an organized body, either animal or vegetable, with a view to ascertaining its internal organization. Technically, the word stands for the knowledge of the structure of organized bodies obtained by their dissection. Anatomy is divided into Animal Anatomy and Vegetable Anatomy; and Animal Anatomy is again divided into Human Anatomy and Comparative Anatomy, the latter being that branch of the science which compares the structure of the human with that of the lower animals.

4. PHYSIOLOGY is the science which treats of the various functions of animal and vegetable organisms and of the changes which take place in such bodies, as the result of the performance of their functions. The subdivisions of physiology are the same as those of anatomy.

[1] From the Greek *bios*—course of life, and *logos*—a discourse.

[2] From the Greek *zoön*—a living creature, and *logos*—a discourse.

[3] From the Greek *botane*—grass.

[4] From the Greek *ana*—up, and *temno*—to cut.

[5] From the Greek *physiologia*—an enquiry into the nature of things.

[6] From the Greek *embryon*—an embryo, and *logos*—a discourse.

[7] From the Greek *histos*—a web or tissue, and *logos*.

5. EMBRYOLOGY is the science which treats of the formation and growth of living organisms, from the moment of their coming into being until they are fully developed.

6. HISTOLOGY is sometimes called *microscopic* anatomy. It is the science which deals with the minute or microscopical structure of organic bodies.

7. RELATION OF PHYSIOLOGY TO CHEMISTRY AND PHYSICS.—The sciences of Chemistry and Physics are intimately connected with the science of Physiology. In fact, the animal body might well be likened to a chemical laboratory, for, from the moment of conception until long after death, chemical processes are incessantly taking place within it.

8. NATURE OF THE PHENOMENA OF LIFE.—Until very recently it was thought that many of the more complicated life processes were due to a so-called *vital principle—i. e.*, an unknown and undiscoverable phenomenon, quite distinct from any ordinary physical or chemical force. But increased knowledge and the improved facilities and equipment of modern laboratories have enabled the chemist and the physiologist to understand enough of the processes occurring within the animal body to lead them to believe that the phenomena of life are dependent upon the working of much the same physical and chemical forces as are active in the rest of the world.

9. CHEMICAL COMPOSITION OF THE ANIMAL

BODY.—Analytical study of the animal body has shown that not only are the life processes taking place within it similar to those occurring in other living processes of nature, but that the body is made up of elements that are very common in nature, viz.:

	(chemical symbol of elements)
Oxygen	O
Carbon	C
Hydrogen	H
Nitrogen	N
Calcium	Ca
Phosphorus	P
Sulphur	S
Sodium	Na
Chlorine	Cl
Fluorine	Fl
Potassium	K
Iron	Fe
Magnesium	Mg
Silicon	Si
Copper	Cu
Lead	Pb
Aluminium	Al

10. The elements present in the animal body in greatest abundance are oxygen, carbon, hydrogen, and nitrogen. These constitute about 97 per cent. of the body. The most abundant of the metallic elements are calcium, sodium, and potassium.

11. With the exception of O, H, and N, these elements are never found in a free or uncombined state in the animal body. O and H have been found in the blood, and N, as well as O and H, in

the intestines, but the bulk of these elements, as well as all of the others that enter into the composition of the body or are present therein in any way, are found in the form of compounds.

12. Nature of Compounds Composing the Animal Body.—The compounds constituting the animal body are of two kinds, namely: organic and inorganic.[1] The organic compounds have been classified according to their chemical composition as *nitrogenous* or *protein compounds* and *non-nitrogenous compounds.*

13. Nitrogenous Compounds.—The composition of the nitrogenous or protein substances is very complex, and that of the majority of them is not known further than that they contain O H C N S and, generally, P and Fe. The principal protein compounds found in the animal body are various forms of albumin, globulin, gelatinoids, and what are known as derived proteins, viz.: the products of katabolism (breaking down) of the other proteins. The nature of these substances will be more fully discussed in the chapters on metabolism and nutrition, and in the glossary.

[1] Organic substances are those possessing life or those produced by living organisms and the term now includes also matter resembling the latter made by man, for the chemist has discovered means of making many compounds that it was once thought could be produced only as the result of living processes. As all such matter contains carbon, organic matter is often defined as "compounds containing carbon." There are, however, a few substances containing carbon (*e. g.*, sodium carbonate) that resemble and are classed with mineral matter and other compounds not endowed with life, as *inorganic matter.*

14. NON-NITROGENOUS SUBSTANCES.—The non-nitrogenous organic substances are divided into two classes, viz.: Carbohydrates and Fats.

15. CARBOHYDRATES.—The principal carbohydrates found in plants are sugars, starch, cellulose, and gums. Of these only glucose (a simple sugar) and glycogen, also termed animal starch, are usually found in animal tissue. Glucose and glycogen are composed of C H O. The chemical formula for glucose is $C_6 H_{12} O_6$, showing that each molecule[1] of glucose is composed of six atoms of carbon, twelve atoms[2] of hydrogen, and six atoms of oxygen. The chemical formula for glycogen is $C_6 H_{10} O_{5n}$.

16. FATS.—Human fat is made up of three simple fats named stearin, olein, and palmitin; and each molecule of these simple fats consists of three molecules of a fatty acid and one molecule of glycerine. The acid from which stearin is derived is known as stearic acid; the foundation of olein is oleic acid; and that of palmitin, palmitic acid.

17. Fats are composed of the same elements as the carbohydrates, viz.: C O H, but the elements are present in different proportions from those in the carbohydrates, and the relative amounts vary in the different forms of fat.

18. INORGANIC MATTER.—The inorganic matter present in the animal body consists of water, mineral salts, and gases.

[1] A molecule is the smallest part of a compound that can exist alone.

[2] An atom is the smallest part of an element that can exist.

19. WATER.—Water constitutes about 70 per cent. of the body weight, and it enters into the composition of both the fluids and the solid tissues of the body. Bone, which is one of the hardest tissues, contains approximately 50 per cent. of water. The chemical formula for water is H_2O.

20. MINERAL SALTS.—A salt is formed by the union of an alkali or base and an acid, and is named after the alkali and acid composing it.[1] Thus, calcium carbonate is a salt formed by the union of the base calcium (lime) and carbonic acid; sodium chloride is derived from the base sodium and hydrochloric acid; magnesium phosphate from the base magnesium and phosphoric acid; sodium sulphate from sodium and sulphuric acid, etc.

21. The most important salts in the animal body are:

Sodium, Potassium	Chlorides	Calcium, Potassium, Sodium	Carbonates
Calcium, Potassium, Sodium, Magnesium	Phosphates	Calcium, Potassium, Sodium	Sulphates

22. To recapitulate: The substance of the body is composed of some seventeen elements, which are formed by chemical union into certain organic and inorganic compounds that are classified as:

[1] See Glossary, for chemical definition and description of alkalies, acids, and salts.

Organic	Proteins	Inorganic	Mineral matter
	Fats		Water
	Carbohydrates		Gases

As will be seen later, both animal and vegetable foods contain similar substances and from these man obtains the matter necessary for growth.

Cells.

23. From the chemist's standpoint the elements named in paragraph 9 are the units or fundamental parts of organic life. From the anatomist's point of view the cell is the unit.

24. NATURE OF PLANT AND ANIMAL CELLS.—The term cell, from the Latin *cella*—a cavity—was used first by botanists who described[1] the plant cell as "a more or less spherical body surrounded by a membrane wall and containing a smaller body termed a nucleus,[2] which, in turn, encloses one or more still smaller bodies or nucleoli." This description is partly true of the majority of plant cells, but it has been found that many animal cells have no wall and are, therefore, not cavities, but minute masses of what has been called *protoplasm*. Another erroneous idea formerly held was that the wall was the essential feature of cells, but, in reality, the wall is secreted by the protoplasm and serves merely for support.

25. NATURE OF PROTOPLASM.—Living proto-

[1] *Handbook of Physiology*, page 2, Kirke. Revised by Frederick C. Busch, B.S., M.D. William Wood & Company.

[2] See next paragraph.

plasm is a semi-fluid, usually colorless, substance which is not miscible with water. Its exact nature is unknown, but it is thought to consist chiefly of water and proteins with various salts and fatty and, sometimes, carbohydrate matter. Viewed under the microscope, it appears as a mass of somewhat granular matter—called *cytoplasm*—containing near its center a minute body—*the nucleus*—and near this a dot—*the centrosome*—that is surrounded by a clear area—the *attraction sphere*. The nucleus is encased in a delicate membrane, it is lined with fibrils, and, usually, contains a spot—*the nucleolus*—the purpose of which is unknown. Also, the nucleus contains material called, because it can be dyed, *chromatin*. The nucleus is essential for the nutrition and multiplication of cells. A cell that parts with its nucleus is no longer a living unit. The centrosome is concerned in cell divisioning.

26. Size of Cells.—The majority of animal cells are from 1/3000 to 1/300 of an inch in diameter.

27. Unicellular Animals and Plants.—Some exceedingly small animals and plants consist of but one cell. The amœba is an example of the former, and bacteria of the latter.

28. Cell Division. All the higher forms of life consist of millions of cells. Those forming the animal body originate from a single cell called the ovum,[1] that becomes fecundated by a cell from

[1] From the Latin *ovum*—an egg. The germ from which offspring are formed, which develops in the ovary of the female animal.

the male animal, called the spermatozoön. Cells multiply by dividing in half and thus forming two cells which, likewise, divide, and so on. They do

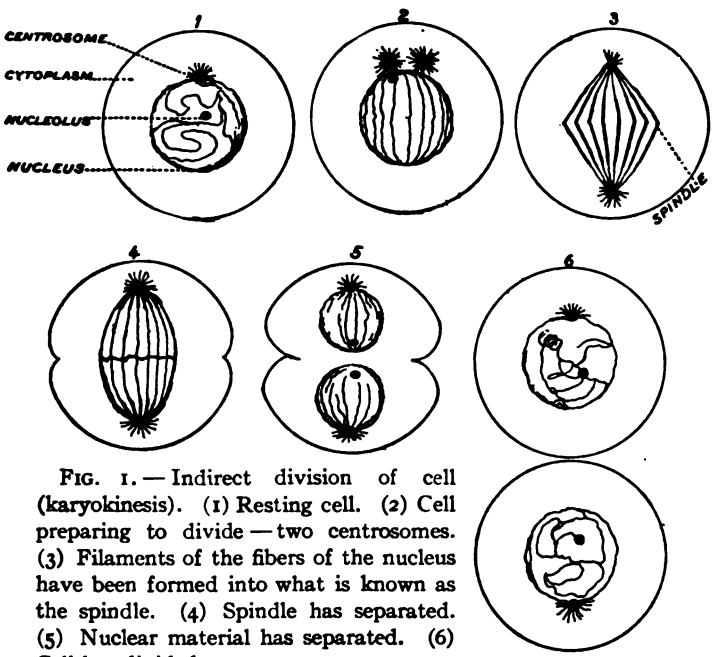

FIG. 1. — Indirect division of cell (karyokinesis). (1) Resting cell. (2) Cell preparing to divide — two centrosomes. (3) Filaments of the fibers of the nucleus have been formed into what is known as the spindle. (4) Spindle has separated. (5) Nuclear material has separated. (6) Cell has divided.

this in two ways, one of which is known variously as *simple* or *direct division*, and *akinesis*—from a Greek word meaning movement. The other method is known as *indirect division* or *mitosis*—from a Greek word meaning a thread,—or *karyokinesis*—from the Greek, movement of a kernel. In direct division the nucleus and cytoplasm be-

come constricted in the center and then split in half. In indirect division, which is the almost universal method, a series of changes is undergone in the fibers of the nucleus before division of either nucleus or cytoplasm takes place.

29. Food Requirement of Cells.—Before a cell divides, by either of the methods referred to in the preceding paragraph, it increases in size and for this growth it must have food. This is the case with every living cell, whether it be animal or vegetable, whether it be a complete body in itself—as an ameba—or only an infinitely small portion of a body. Also every living cell requires food because some of its substance is being constantly broken down as the result of its life activities.

This destruction of cell substance, which is known as *katabolism*,[1] and repair, termed *anabolism*,[2] will be further discussed under *metabolism*.[3]

30. Difference in Cells.—Cells are not all exactly alike, either in their chemical constituents or function, and the higher the animal is in the scale of life the greater will be the variety of the cells composing it, and the more complex and highly specialized some of these cells will be. Certain of the important points of difference will be referred to in the chapters describing the various kinds of tissue of which the human body is composed.

[1] From the Greek *katabole*—a throwing down.

[2] From the Greek *anabole*—a throwing up.

[3] From the Greek *metabole*—a change. The chemical changes of katabolism and anabolism are known as metabolism.

CHAPTER II

DIVISIONS OF THE BODY

Organs. Systems. Anatomical Position. Surfaces of the Body. Main Divisions of the Body. Cavities and Organs in Each Cavity. Regions of the Abdomen. Words Used in Describing the Location of Different Parts of the Body.

31. ORGANS.—As stated in the preceding chapter, the animal body consists of an aggregation of cells formed into tissues of varying nature. Many of these tissues are in turn moulded into *organs*, *i. e.*, parts capable of performing some special function—as the heart, stomach, lungs, etc.

32. SYSTEMS.—Each individual organ of the body has its own work to perform, but in no case is one organ sufficient for the carrying on of any one complete function of the body, and the organs that are dependent upon each other for the perfecting of their functions are in description grouped together in what are called *systems*, *e. g.*, the circulatory system, the respiratory system, etc. Even the systems of the body are dependent upon each other for the carrying on of their work, *e. g.*, all the organs are dependent upon the circulatory system for their existence, and the functioning of

the various systems would be useless to the body as a whole were it not for the nervous system, which affords a species of telegraphic communication between the different parts of the body, so that all can work in harmony.

In several instances one organ forms a part of more than one system; thus, the pharynx is an adjunct of the organs of speech, of the respiratory system, and of the digestive system.

33. On account of this interdependence of the different organs and systems it is important for the student, before taking up their study in detail, to gain a general idea of the comparative location of the several parts of the body, and this can be best done by a careful inspection of the skeleton and of the manikin, or, if such are not to be had, of the various plates in this book. Also, it is necessary to know the names that anatomists have given to the surfaces and cavities of the body in order to facilitate description and the localizing of organs. These are as follows:

34. The Anatomical Position.—Those describing the various surfaces and regions of the body always consider the figure as standing with the face toward the observer, the palms of the hands turned forward. This constitutes what is known as the *anatomical position*.

35. Surfaces of the Body.—With the figure in the anatomical position, the front surface—*i. e.*, the surface facing the observer—is called the anterior or the ventral surface; and the back, the

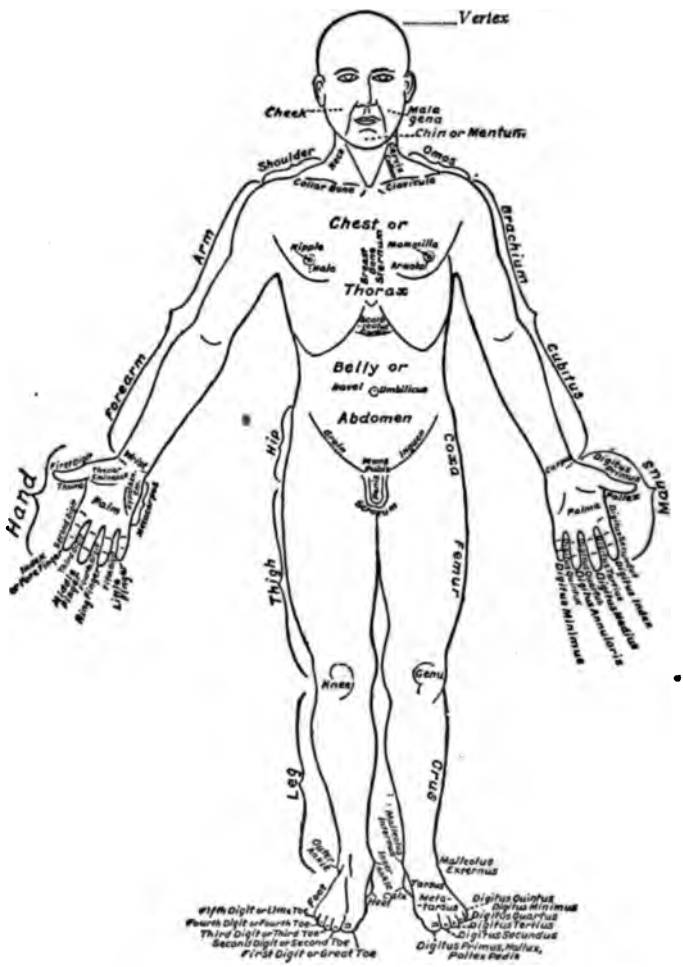

FIG. 2.—Front view of a man in the anatomical position. On one lateral half the parts are labelled in English, on the other in Latin. The right upper limb is drawn away from the trunk in order to show the arm more fully than is possible when it hangs perpendicularly.

posterior or the dorsal surface.

36. Divisions of the Body.—The main divisions of the body are the head, the neck, the trunk or torso, and the upper and lower extremities. The trunk is divided into the chest or thorax, abdomen, pelvis. Each upper extremity or limb is divided into the arm—the part between the shoulder and the elbow—the forearm, and the hand. Each lower extremity is divided into the thigh—the portion between the hip-bone and the knee—the leg, and the foot. For the location of these and minor divisions see Figs. 2 and 3.

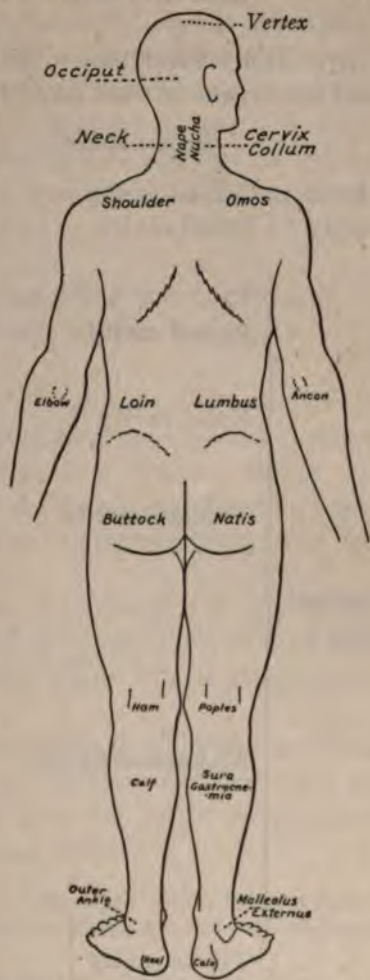

Fig. 3.—Back view of a man. On one lateral half the names of the parts are given in English, on the other in Latin.

37. BODY CAVITIES.—The cavities of the body and the organs in each cavity are as follows:

	Body Cavities.		*Organs in Cavity.*
Dorsal cavity	Cranial cavity		Brain
	Spinal cavity		Spinal cord
Ventral cavity	Buccal cavity		Tongue, Teeth, Salivary glands, Tonsils
	Nasal cavity		
	Thoracic cavity		Esophagus, Trachea, Lungs, Heart, Blood and lymph vessels
	Abdominal cavity		Stomach, Spleen, Pancreas, Liver, Gall-bladder, Kidneys, Large and small intestines
	Pelvic cavity		Urinary bladder, Rectum
		(Female)	Generative organs

38.—REGIONS OF THE ABDOMEN.—For the purpose of description, the abdomen is considered as being divided into nine *regions*, namely: the right

hypochondriac,[1] the epigastric,[2] the left hypochondriac, the right lumbar,[3] the umbilical[4] the left lumbar, the right inguinal,[5] the hypogastric, and the left inguinal. The relative position of these regions can be seen in Fig. 4. The regions will be further discussed in connection with the organs of digestion, Chapter XVII.

Words Used in Describing the Location of Different Parts of the Body.

39. MEDIAL AND LATERAL.—By medial is meant the part nearest what is known as the median line, *i. e.*, an imaginary line drawn through the middle of the head and trunk to the floor between the feet; and by lateral, the part farthest from the line.

40. INTERNAL AND EXTERNAL.—These words are often used instead of medial and lateral, but are also employed to designate within and without the body.

41. PROXIMAL AND DISTAL.—The former word is used in referring to position near the head or source of any part, and the latter to position farthest from the head or source.

[1] Hypochondriac, from the Greek *hypo*—under, and *chondros*—a cartilage. The hypochondriac regions are under the cartilage of the ninth rib.

[2] Gastric, from the Greek *gastro*—the belly, and *epi*—over.

[3] Lumbar, from the Latin *lumbaris*—the loin.

[4] Umbilical, from the Latin *umbilicus*—the navel.

[5] Inguinal, from the Latin *inguinalis*—the groin.

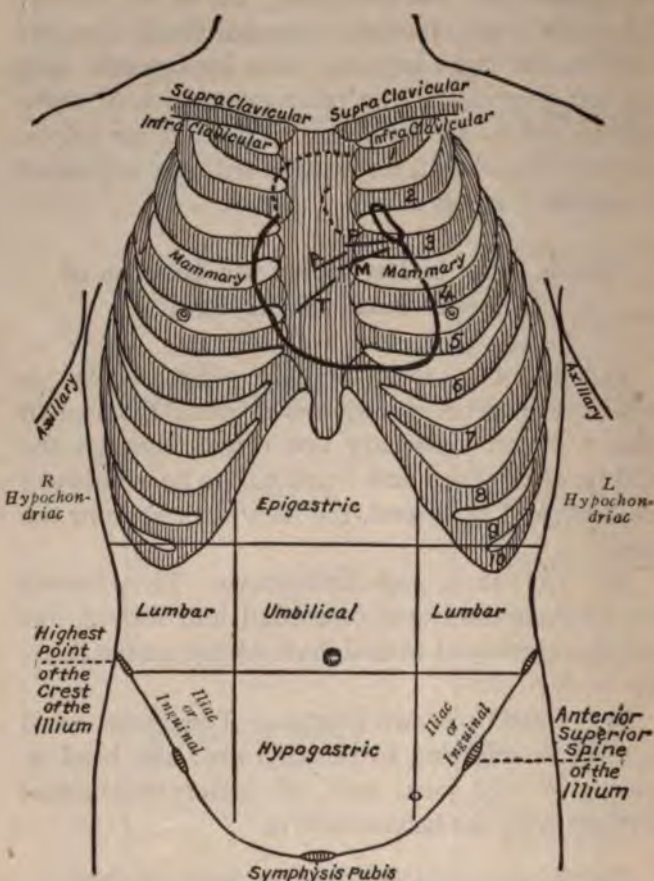

FIG. 4.—Diagram of Thoracic and Abdominal Regions.

Heart { *A.* Aortic valve. *M.* Mitral valve. Heart { *P.* Pulmonary valve *T.* Tricuspid valve.

42. PERIPHERY.[1]—This means the outer circumference, the part farthest from the center.

43. AFFERENT [2] AND EFFERENT.[3]—These two words are used more especially in connection with the nerves and blood-vessels; afferent means to carry to, and efferent to carry from.

44. CENTRIPETAL [4] AND CENTRIFUGAL.[5]—The former means traveling toward the center; the latter, receding from the center, *i. e.*, toward the periphery.

[1] From the Greek *periphereia*—the circumference of a circle.
[2] From the Latin *ad*—to, and *ferre*—to carry.
[3] From the Latin *ef*—out, and *ferre*—to carry.
[4] From the Latin *centrum*—center, and *petere*—to seek.
[5] From the Latin *centrum*—center, and *fugere*—to flee.

CHAPTER III

TISSUES

Origin of Tissue. Nature and Definition. Classification. Epithelial Tissues: Nature, Varieties, Location, Function. Connective Tissues: Varieties, Reason for Classification, Distribution. Fibrous Tissue: Varieties, Nature, Distribution, and Purpose of Each Variety. Tendons. Ligaments. Fascia. Aponeuroses. Adipose Tissue: Distribution, Structure, Uses. Lymphoid, Retiform, or Adenoid Tissue: Structure, Purpose. Cartilage: Varieties, Nature, Use, and Location of Each Variety.

45. ORIGIN OF TISSUE.—Every cell of the animal body is descended from one cell, the female germ cell or ovum, that has been made fertile[1] by the entrance of a male cell—the spermatozoön. A human ovum measures about 0.2 mm.—$\frac{1}{125}$ of an inch—in diameter. It is surrounded by a transparent membrane. Its cytoplasm contains numerous yolk or vitellus granules intended for food for the embryo in the very early stages of development. In the midst of the cytoplasm is the nucleus or germ vesicle and within this is the nucleolus and a substance called *chromatin*. The male cell also contains chromatin. The chromatin develops into threads called *chromosomes* and these

[1] See Chapter XXV.

contain the principle that transfers hereditary traits from parents to offspring. After impregnation takes place the ovum divides and subdivides until the number of cells increases to many millions. At first these cells appear to be all alike, but after a few days they become arranged into three distinct layers, see Fig. 135, and the nature and purpose of each layer are different from those of the others. From the outermost layer—called the *epiblast* [1]—the skin and nervous tissue are derived. The innermost layer—the *hypoblast* [2]—is the source of the greater part of the alimentary and respiratory tracts, the liver, pancreas, and other glands. From the middle layer—the *mesoblast* [3]—the circulatory and urino-genital systems, also the muscles, bones, and other connective tissues of the body are developed.

46. Thus it can be see that the structure of the body consists for the most part of masses of cells derived from a single cell,[4] and that these cells gradually develop special characteristics which enable them to perform their functions.

47. Nature and Definition of Tissue.—The cells are held together either by a cement-like substance derived from the cells and called *intercellular substance*, or else by anastomosing pro-

[1] From the Greek *epi*—upon, and *blastos*—a sprout germ.
[2] From the Greek *hypo*—below, and *blastos*—a sprout germ.
[3] From the Greek *mesos*—middle.
[4] The ovum and spermatozoön combined are usually considered as one cell, because neither one alone contains all the essentials necessary for cell division and growth.

cesses on the surface of the cells. The substance formed by these aggregations of cells and intercellular substance is called *tissue*. Literally tissue means a web-like structure or a woven fabric, but as the word is used in anatomy it stands for any organized[1] substance in the body.

48. CLASSIFICATIONS OF TISSUES.—According to the purpose which the various kinds of tissue serve in the body, they have been classified as:

(1) Epithelial tissues: tissues covering the free surfaces of the body;

(2) Sustentacular or connective tissues: tissues passively supporting and connecting other parts as:

Fibrous tissue
Adipose tissue
Lymphoid, retiform, or adenoid tissue
Cartilage
Bone and dentine;

(3) Liquid tissues: tissues performing a nutritive function, viz: blood and lymph;

(4) Muscular tissues: tissues devoted to movement;

(5) Nervous tissues: tissues essential to sensation.

Epithelial Tissues

49. LOCATION.—Epithelial tissues are those which cover the surfaces of the body, *e. g.*, the

[1] The words organized and organic must not be confused. Organized tissue is that with a definite structure; it may consist of either organic or inorganic substances, or both.

outer or scarf skin; the covering of the mucous membrane, *i. e.*, the membrane which lines those passages and cavities that communicate with the exterior of the body, as the alimentary canal, the respiratory and urinary organs; the covering of the serous membrane, *i. e.*, the membranes lining the closed cavities of the body, as the thoracic cavity and the abdominal cavity. Epithelial tissue also lines the glandular organs.

50. NATURE.—Epithelial tissues consist of cells placed in close contact with each other and spread out so as to form a thin sheet of tissue known as *epithelium*. The cells composing this variety of tissue are of different shapes, and the tissue often receives its distinctive name from the shape of its cells. The only name of particular importance for nurses to remember is *ciliated epithelium*.

FIG. 5. Two conoidal epithelial cells, their free ends furnished with cilia.

51. CILIATED EPITHELIUM. — The cells composing this form of epithelium are columnar in shape; they are packed closely together and have a number of small hair-like processes called cilia extending from their free edge. The cilia have a constant vibrating motion with a strong stroke in one direction and a weak one in the other; this serves to protect the orifices and cavities which they line against the entrance of foreign substances. This form of epithelium, in the adult, is found mainly in some of the respiratory

organs and in some of the organs of generation. In children it is found also in the central canal of the spinal cord and the ventricles of the brain.

52. Functions of Epithelial Tissue.—The more common functions of epithelial tissue are protection, secretion, and sensation.

Protection.—Epithelial tissue protects the body in several ways: (1) it affords an almost impermeable covering for the body; (2) the vibratory movement of the cilia brush away foreign substances from the cavities lined by that form of epithelium; (3) the epithelial cells covering the serous and mucous membranes take an active part in secreting the fluid which moistens, lubricates, and thus protects those membranes.

Secretion.—The cells of the epithelial lining of the glandular organs and, as stated in the preceding paragraph, those of the covering of the mucous and serous membranes are the active agents in the process of secretion that is characteristic of such organs and membranes. The process of secretion and the secretory organs will be described in Chapter XVI.

Sensation.—In parts of the nose, mouth, eyes, and ears, in close connection with the terminal filaments of the nerves devoted to smell, taste, hearing, and sight, are cells called, by virtue of their office, sensory or neuro-epithelial cells. Such a cell is attached at one end to the peripheral ending of a sensitive nerve, and its free end, which is generally prolonged into a stiff, hair-like process, projects beyond the surrounding surface. Any

agitation in the media around these projections causes a vibratory movement in the cells which agitates the nerve endings and causes the nerves to carry impressions to the brain.

The Sustentacular or Connective Tissues

53. Tissues Belonging to Sustentacular or Connective-Tissue Group.—The tissues classified under this heading are:

Fibrous tissue { Areolar / White / Yellow or elastic

Adipose or fatty tissue
Retiform, adenoid, or lymphoid tissue
Cartilage
Bone, and dentine

54. Reason for Classification.—Though some of these tissues vary considerably in their composition, they are all classed under the same heading: because (1) they are (as stated in paragraph 45) all developed from the same embryonal element; (2) they serve the same purpose in the body, namely: they act as a framework, as a support, and as a connecting link between the various parts and organs of the body; (3) they are all passive, *i. e.*, they originate no action, they do nothing of themselves, but are active only when influenced by other tissues.

55. Distribution.—Connective tissues are very widely distributed in the body; in fact, they

are so closely interwoven with its substance that if all other tissues were removed the connective tissues left would give a very exact though porous-looking model of every tissue and organ of the body.

Fibrous Connective Tissue

56. VARIETIES.—There are three main varieties of fibrous tissue: viz., areolar tissue, white fibrous tissue, and yellow or elastic tissue.

Areolar Tissue

57. *Nature and Distribution.*—If the skin of a

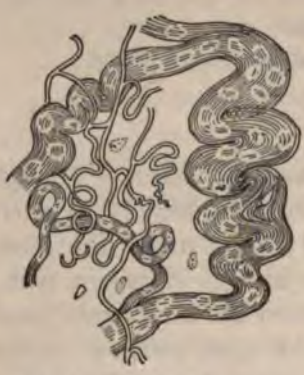

FIG. 6.—Areolar tissue, composed of bundles of white fibrous tissue and branched strands of yellow fibrous tissue loosely intertwined.

FIG. 7.—A portion of areolar tissue inflated and dried, showing areolæ.

dead animal is cut and raised in any part where there is not much fat, a filmy, tenacious, slightly

elastic meshwork of tissue will be seen holding the skin to the flesh beneath it. This is areolar tissue. It will be found also under mucous membrane, and investing the muscles, nerves, blood-vessels, and internal organs, and penetrating into the substance of the latter, holding their tissues together.

58. *Structure.*—Examined under the microscope, areolar tissue appears to be composed of innumerable fine, wavy fibers or threads and bundles of such fibers interlacing each other in all directions, with open spaces between the fibers and various kinds of tissue cells in some of these spaces.

59. NATURE OF WHITE FIBROUS TISSUE.—White fibrous tissue is a white, shiny, tough, pliant, but not elastic, tissue. Seen through the microscope it appears to consist of long, generally parallel bundles of fibers, with chains of cells separating the bundles.

FIG. 8.—White fibrous tissue.

FIG. 9.—Cells of white fibrous tissue, often called connective-tissue cells.

60. NATURE OF YELLOW FIBROUS OR ELASTIC TISSUE.—The general structure of this form of fibrous tissue is very similar to that of the white, but it is usually of a yellowish color and is elastic.

61. ELASTICITY OF TISSUE.—Both yellow and white fibers often enter into the composition of the

same tissue, and the degree of elasticity of the part will depend upon the proportion in which the two varieties of fibers are present.

62. Function of Fibrous Tissue.—Fibrous tissue serves several purposes in the body: (1) It holds the bones together at their places of juncture or *articulations;* (2) It attaches muscles to the bones; (3) It connects the muscles to each other; (4) It envelops muscles and holds them, as well as other tissues, in place; (5) It serves as a support for blood-vessels, nerves, etc.; (6) It forms part of the substance of many of the body organs and membranes; (7) It forms the foundation for certain of the other tissues, as fat and bone.

63. Different Shapes and Names of Fibrous Tissue Holding Bones and Other Tissues Together.—The fibrous tissues which serve to connect bones, muscles, etc., are usually in the form of either broad sheets, bands, or cords, and are known as ligaments,[1] tendons[2] or sinews, fasciæ,[3] aponeuroses,[4] sheaths, or membranes.

64. Ligaments—*Nature and Purpose.*—Ligaments are strong, flexible bands of fibrous tissue, which serve chiefly to attach muscles to bones and to hold the latter together at their articulations. Those holding together bones of freely movable joints, as the shoulder and hip joints, where free

[1] Ligament. From the Latin *ligamentum*—a band.
[2] Tendons. From the Latin *tendo*—to stretch.
[3] Fascia. From the Latin *fascia*—a band.
[4] Aponeuroses (sing. aponeurosis). From the Greek *apo*—from and *neuron*—a sinew or tendon.

movement but no extension is desired, are composed of the white variety of tissue. Those connected with joints where limited motion combined with extensibility is desired, as between the arches of the vertebræ, consist of both yellow-elastic and white fibers.

65. TENDONS OR SINEWS—*Nature.*—Tendons are white, glistening, fibrous cords, some of which are flat and some round. The majority of them are composed chiefly of white fibers, but many of them contain a varying quantity of yellow fibers and are thus slightly elastic. Tendons are very sparingly supplied with nerves and blood-vessels.

66. *Function.*—Tendons serve to attach muscles to bone. They extend from a muscle over a joint and their fibers blend with those of the periosteum of the bone beyond. As muscles are always in a state of tone they pull on the tendons, and this tension helps to hold bones of a joint in place and facilitates movement when a muscle contracts.[1]

67. FASCIA—*Nature and Purpose.*—Fasciæ are sheets or broad bands of fibrous tissue. They are classified as superficial and deep. The former consists of the areolar tissue that holds the skin to the underlying tissue. The deep fasciæ comprise the sheets of fibrous tissue which envelop the muscles and both separate them and hold them together. The fascia covering the palms of the hands is known as *palmar fascia*, and that cover-

[1] See page 107.

ing the soles of the feet as *plantar fascia.* The palmar and plantar fasciæ are much thicker and stronger than the fasciæ in other parts of the body. The more important of the other deep fasciæ have been named either after the muscle they cover or the part of the body in which they are located.

68. APONEUROSES—*Nature and Purpose.*—Aponeuroses are virtually flat, wide tendons, and they serve very much the same purpose as the latter, but they more often connect the ends of muscles to each other than to bones.

69. Aponeuroses are destitute of nerves, and only the thicker ones are supplied with blood-vessels.

Adipose Tissue

70. DISTRIBUTION.—Adipose or fatty tissue is

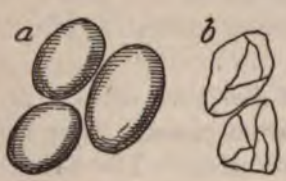

FIG. 10.—Fat-cells: *a*, filled with oil; *b*, exhausted of oil, the cell-wall shriveled.

FIG. 11.—Fat-cells packed closely together, and thus becoming polyhedral.

found in nearly all parts of the body; exceptions are the substance of the lungs and liver, the subcutane-

ous tissue of the eyelids, penis,[1] and scrotum.[1]

71. STRUCTURE.—Adipose or fatty tissue consists of a number of closely packed vesicles, the walls of which are formed of an exceedingly delicate structureless membrane derived from areolar tissue. These vesicles which average about 1/500 of an inch in diameter, are filled with fatty[2] matter, which is liquid during life but becomes solidified after death.

72. USES.—Adipose tissue serves several purposes in the body: (1) It acts as a store of energy material for the body, for when the system requires matter for the production of heat and energy[3] the fatty substance can be oxidized; (2) The fat under the skin, being a non-conductor of heat, prevents the too rapid loss of heat through the skin; (3) It fills spaces in the tissues and thus affords support for, and prevents pressure on, delicate structures such as blood-vessels and nerves; (4) Fat is collected in large masses around the kidneys and helps to retain them in place.

Lymphoid, Adenoid, or Retiform Tissue

73. STRUCTURE.—Lymphoid tissue, known also as adenoid and retiform tissue, consists chiefly of

[1] See Chapter XXV., Organs of Generation.

[2] The nature of this fatty matter is discussed in paragraphs 16 and 17.

[3] The production of heat and energy and oxidation are described in the chapters dealing with food, metabolism, and heat regulation.

a delicate meshwork[1] of white fibers covered with flat cells. The interstices of the network are filled with lymph cells and the tissue is cemented together with an almost fluid intercellular substance.

Purpose.—Lymphoid tissue forms the stroma—*i. e.*, the bed or principal part of the substance—of the spleen and lymphatic glands; also it enters into the composition of the thymus gland, the tonsils, some of the intestinal glands, and the mucous membranes.

74. In childhood an abnormally large amount of this tissue often develops in the naso-pharynx[2] and the child is then said to have *adenoids*. Common causes are colds and the sucking of pacifiers.

Cartilage[3]

75. NATURE AND WHERE FOUND.—Cartilage, commonly known as gristle, is an exceedingly tough, strong, and, except the white variety, elastic tissue. In the adult the cartilage is found chiefly in the joints, in the walls of the thorax—chest,—and in various tubes such as the air-passages, nostrils, and ears, which are to be kept permanently open. In the fetus the greater part of the skeleton is at first cartilaginous, and this cartilage, as it is afterward replaced by bone, is called *temporary* cartilage, in contradistinction to

[1] The meshwork is sometimes called retiform tissue and the combined meshwork, cells, and intercellular substance, lymphoid or adenoid tissue.

[2] Described in paragraph 602.

[3] From from the Latin *cartilago*—gristle.

that which remains unossified during life, which is called *permanent* cartilage.

76. Structure and Classification.—Cartilage is composed chiefly of a substance known as collagen, which is resolved into gelatin by boiling. It consists of cells imbedded in an intercellular substance called the *matrix*.[1] The matrix varies somewhat in composition, and according to this variation cartilage is known as:

Hyaline[2] cartilage
Yellow-elastic cartilage
White fibro-cartilage

Fig. 12.—White fibro-cartilage.

77. Blood Supply—Perichondrium.[3]—Cartilage is not supplied with either blood-vessels or nerves; the hyaline variety usually obtains its nutrient from the bones which it covers; the yellow and white cartilages from the vascular fibrous membrane called the perichondrium, which envelops them.

Hyaline Cartilage

78. *Appearance of Matrix.*—In appearance

[1] From the Latin *mater*—mother.
[2] From the Greek *hyalos*—glass.
[3] From *peri*, a prefix used with words of Greek origin, meaning about, around; and *chondrin*—a cartilage.

the matrix of hyaline cartilage resembles ground-glass, being slightly transparent but somewhat granular.

79. *Uses and Distribution.*—(1) Hyaline cartilage covers the articulating surfaces of bones for the purpose of preventing friction between the moving parts. Cartilage serving this purpose is called *articular cartilage.* (2) The hyaline variety of cartilage forms the costal cartilages[1] which serve to prolong the ribs forward to the sternum. Costal cartilage being very strong and elastic, though more yielding than bone, helps very considerably in the respiratory movements of the chest walls. (3) Hyaline cartilage forms also an important part of the structure of the nasal passages, the larynx,[1] trachea,[1] and bronchi,[1] and being tough, hard, and firm it serves to maintain their shape and to afford an attachment for their muscles.

Yellow-Elastic Cartilage

80. *Structure.*—The matrix of elastic cartilage consists chiefly of a network of fine elastic fibers, and is very similar to elastic fibrous tissue.

81. *Where Found.*—Elastic cartilage enters into the structure of the external ear, the Eustachian tubes,[2] the epiglottis, and parts of the larynx.

[1] Described in Chapter XV.

[2] The fine tubes extending from the middle cavity of the ear to the pharynx, *i. e.*, the space behind the mouth.

White Fibro-Cartilage

82. *Structure.*—White fibro-cartilage resembles the yellow in its structure, but the fibers of its matrix are white and non-elastic. They resemble those of white fibrous tissue, but are tougher and firmer.

83. *Distribution and Purpose.*—White cartilage is found connecting, or helping to connect, articulating bones, in places where great strength is required, as the knee joint, the pubic bones, and the vertebræ of the spinal column. In the last named location the cartilage is in the form of thick disk-shaped pads, and these are placed between the vertebræ, where they serve not only to hold the bones together, but also to prevent concussion between them.

Another purpose of white cartilage is that it forms sheaths for the tendons, and sometimes enters into their substance, and being even stronger than the fibrous tissue of which the tendons are mainly composed, the cartilage serves to increase their strength.

CHAPTER IV

BONE OR OSSEOUS[1] TISSUE

Tissue of which the Skeleton is Composed. Function of the Bones. Composition of Bone. Nature of Organic and Inorganic Matter in Bone. Comparative Proportion of Each in Bone. Difference in Fractures in Children and Adults. Cause of Rickets. How the Composition of Bone can be Studied. Classification of Bones. Structure of Bone. Markings of Bones. Purpose of Prominence and Depressions of Bones. Nature and Purpose of Parts Composing Haversian System. Marrow, Nature and Purpose. Periosteum. Endosteum. Repair of Bone. Number of Bones Comprising the Skeleton, their Nature, Names, and Location.

84. The bones of which the hard framework or skeleton[2] of the body is composed consist of bone or osseous tissue.

85. FUNCTION OF THE BONES.—The purposes which the bones serve are: (1) to give support and shape to the body; (2) to act as a foundation and afford places of attachment for the soft parts; (3) to support the weight of the trunk; (4) to act as levers for locomotion and other movements of the body; (5) to form cavities to hold the vital

[1] From the Latin *os*—a bone. Plural *ossa*. The branch of anatomy treating of the structure, arrangement, and uses of bone is called osteology, from the Greek *osteon*—a bone and *logos*—a discourse.

[2] Skeleton. Greek, a dried body.

organs; (6) to afford protection for those organs.

86. Composition of Bone.—Bone consists of about 50% water and 50% solid matter. The solid matter comprises both organic and inorganic substances.

87. Nature of Organic Matter.—The organic matter consists chiefly of cartilage and blood-vessels. The cartilage, it will be remembered, is composed principally of a substance known as collagen, which is transformed into gelatin by boiling.

88. Nature of Inorganic Matter.—The inorganic matter, known also as mineral and earthy matter, consists almost entirely of phosphate of calcium and carbonate of calcium.

89. Comparative Proportion of Organic and Inorganic Matter.—The comparative proportion of organic and inorganic substance in bones varies with age; thus in the fetus the tissues that later, by taking mineral[1] and other matter from the blood and incorporating it into their substance, become bone, are largely cartilaginous or fibrous. In young children the animal matter is still in excess of the mineral; in the bones of adults, on the other hand, there are about two parts of inorganic substance to one of organic, and in the bones of old persons the per cent. of inorganic matter is even larger.[2]

[1] Lime.

[2] With a few exceptions the bones of the head and face are preformed in membrane and those of the trunk and limbs in a

90. Difference in Nature of Fractures Due to Variation in Composition of Bone.—As the result of this preponderance of mineral material, the bones of the aged are very brittle and, therefore, easily broken. On the contrary, the bones of children, owing to the large amount of gelatinous substance therein, are very flexible, so that they bend, but do not break readily. In consequence of this difference in composition, accidents that in adults will cause a complete severance of a bone will in children merely bend it or cause an incomplete or partial break, such as that likely to occur in bending a green tree twig. This kind of fracture is therefore known as a *green-stick* fracture.

91. Cause of Rickets.—Children who do not get food containing sufficient mineral matter will have an even smaller proportion of this substance than usual in their bones, in consequence of which the latter are likely to become bent, even without the intervention of an accident. This condition is known as rickets or rachitis.

92. How the Composition of Bone can be Studied.—(1) Put a piece of bone, about four inches in length, in a bottle containing sufficient dilute hydrochloric acid to cover the bone, and let

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cartilage that is covered with a vascular membrane. Bone forming cells, called osteoblasts, and lime salts are gradually deposited in the membrane forming the skull, and in the cartilage fore-plan of the trunk and limbs, and as the bone tissue develops the cartilage is broken down, absorbed, and carried away by the blood. The process of bone formation is spoken of as ossification.

it stand for a few days. The hydrochloric acid will dissolve the mineral matter, and the bone (which is now more like cartilage) can be easily bent and knotted, as in Fig. 13.

FIG. 13.—Human bone which has been deprived of its earthy matter and tied in a knot.

(2) Burn a small piece of bone. The remaining ash is the mineral matter which, on chemical analysis, has been found to consist chiefly of phosphate and carbonate of calcium or lime. The organic matter has been destroyed by the heat; that is, it has been broken down into its elements—C H O N—which have passed off into the air.

93. CLASSIFICATION OF BONES.—Bones are classified according to their shape as long, short, flat, and irregular. The most typical long bones are those of the arms and legs; examples of the short bones are those of the wrist and ankle; of the flat bones, the shoulder-blades, pelvis, and larger bones of the skull; of the irregular bones, the vertebræ of the spine and the temporal and ethmoid of the skull.

Also, there are what are known as the sesmoid[1] and Wormian[2] bones.

[1] From the Latin *sesame*—bones resembling the seeds of the sesame.

[2] Called after a famous Dutch naturalist.

94. The *sesmoid* bones are small, osseous masses developed in tendons at points where they are stretched over joints and exposed to pressure. A patella or knee-cap is an example of a sesmoid bone.

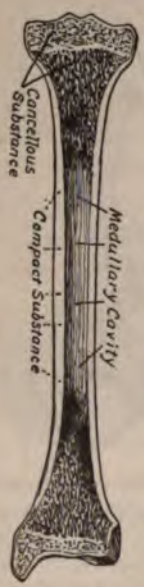


FIG. 14.—The longitudinal section of a long bone.

95. The *Wormian* bones are small, irregular ossicles found on the edges of the cranial bones where the latter come together.

96. STRUCTURE OF BONE.—On examining pieces of bone from different parts of the skeleton it will be seen that the substance of the majority of them is much more dense on the outside. Also it will be noticed that the relative proportion of dense or compact tissue—as the outer substance is called—and spongy or cancellous[1] tissue—the more porous substance—varies in the different kinds of bones. Thus, it will be seen that in the long bones of the arms and legs, where great strength is required, there is no cancellous tissue except at the extremities, and in bones, as some of those of the skull, where lightness and not strength is required, there

[1] Def.: having an open or porous structure. From the Latin *cancellus*—a lattice-work. The composition of compact and cancellous tissue is the same, the difference in their appearance being due to the larger size of the spaces between the lamellæ or framework.

is less compact substance. Other points to be observed are: (1) the canal or cavity extending through the center of the shaft of each long bone, called the *medullary*[1] *canal* because it contains the *medulla* or *marrow;* and (2) the markings of the bones.

97. Markings of the Bones.—Many of the bones show certain irregularities on their surface known as *markings*. These markings are of various characters and each variety is distinguished by a special name. Thus, projections are called processes, and rounded processes *which do not articulate* with other bones are called *tuberosities*,[2] and smaller ones *tubercles*,[3] and rounded processes *which do articulate* with other bones are called condyles[4] and heads; long, sharp, slender processes are known as *spines;* prominent borders are called crests. Holes through a bone are termed *foramina* (sing. *foramen*[5]); non-articular depressions are known variously as *fossa*, *grooves*, *fissures*, *notches;* articular depressions are called *cavities*. A constricted portion of bone beneath a head is called a *neck*, and the long straight portion of the long bones, *shafts*. See Figs. 41, 42, 43.

98. Purpose of Prominences and Depressions of Bones.—Articular processes fit into articular depressions and thus the strength of a

[1] Latin *medulla*—marrow.
[2] Tuberosities
[3] Tubercles } Latin *tuber*—a swelling.
[4] Greek *kondulos*—a knob.
[5] Latin *foramen*—an aperture, a hole. Plural *foramina*.

joint and evenness of movement are secured. Non-articular eminences and depressions serve to increase the extent of surface for the attachment of ligaments and muscles.

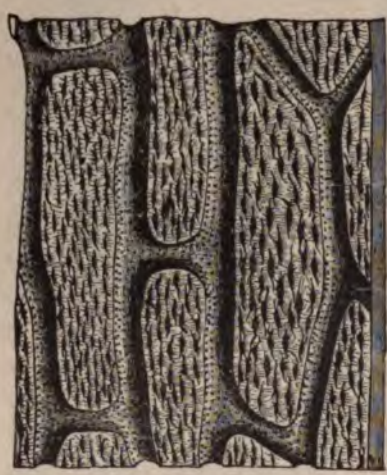


FIG. 15.—Longitudinal section of compact osseous tissue, greatly magnified. The Haversian canals are cut lengthwise. The dots in the canals are openings of canaliculi. (Gerrish.)

99. HAVERSIAN SYSTEM. — After examining the gross structure of the bones it is well, if possible, for the student to examine a few thin slices of bone under the microscope. It will be then seen that even in the dense tissues of the shafts of the long bones there are (1) several apertures that in the bone as a whole would constitute longitudinal canals; (2) that each of these canals has smaller canals radiating from it, somewhat like the spoke of a wheel, and communicating with small, irregular, open spaces; (3) that these open spaces, of which there are several rings (see Fig. 16) communicate with each other by means of small canals similar to the ones connect-

ing them with a longitudinal canal, so that there is free communication between the latter and the spaces. The longitudinal canals are called *Haversian canals*—after Havers, a famous anatomist; the smaller ones are called *canaliculi*[1]; the spaces are termed *lacunæ*[2]; the bony fibers comprising the framework between the open parts and constituting the solid portions of the bone are known as the *lamella*,[3] and the whole arrangement combined is called an *Haversian system*.

100. Purpose and Distribution of Haversian Canals, etc.—Lacunæ and canaliculi serve as pathways for the lymph[4] through the bone; they are present in all true bones; but Haversian canals, which serve as tubes to hold the blood and lymph vessels, and nerves are not found in bones which are so thin that they can obtain nourishment from blood-vessels on their surface.

101. Marrow—Nature and Purpose.—In the living bone the medullary canal of the shafts of the long bones and the open spaces of the cancellous tissue are filled with a substance known as marrow. This consists chiefly of a small amount of fibrous tissue with blood-vessels, fat-cells, marrow-cells, and red blood-cells. The marrow in the medullary canals contains a larger per cent. of fat than that in the cancellous substance, and is yellow in color. That in the

[1] From the Latin *canaliculus*, dimin. of *canalis*—a channel.
[2] Latin *lacuna*—a hollow. Pl. *lacunæ*.
[3] Latin—a thin plate. Pl. *lamellæ*.
[4] Described in paragraph 494.

cancellous substance is highly vascular and, consequently, has a reddish hue. The chief uses of marrow are: (1) to serve as a source of nourishment for the bone; (2) to support blood- and lymph-vessels and nerves; (3) as a location for the formation of blood corpuscles (see paragraph 461).

102. PERIOSTEUM—BLOOD AND NERVE SUPPLY OF BONE.—The outer surface of bones, except at their joints, where they are protected with cartilage, are covered with an exceedingly vascular membrane called the *periosteum.*[1] The blood-vessels running through the canals of the bones are for the most part branches of those of the periosteum; therefore destruction of the periosteum of a bone will interfere with the nutrition of the latter and may result in necrosis—*i. e.*, death of the bone. The marrow in the medullary canal of the shaft of the long bones is supplied with blood also by a medullary artery, which penetrates the compact tissue obliquely and then divides into two main branches, one of which ascends and the other descends in the canal.

103. The periosteum and bone are supplied also with nerves. These run in the same channels as the blood-vessels.

104. ENDOSTEUM.—The medullary and cancellous cavities of the bones are lined with a membrane similar to the periosteum, known as the *endosteum.*[2]

[1] From the Greek *peri*—about, and *osteon*—a bone.

[2] From the Greek *endon*—within, and *osteon*—a bone.

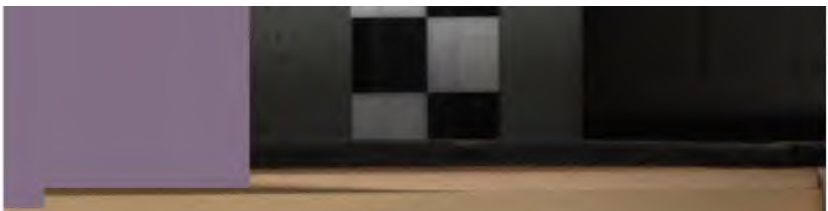
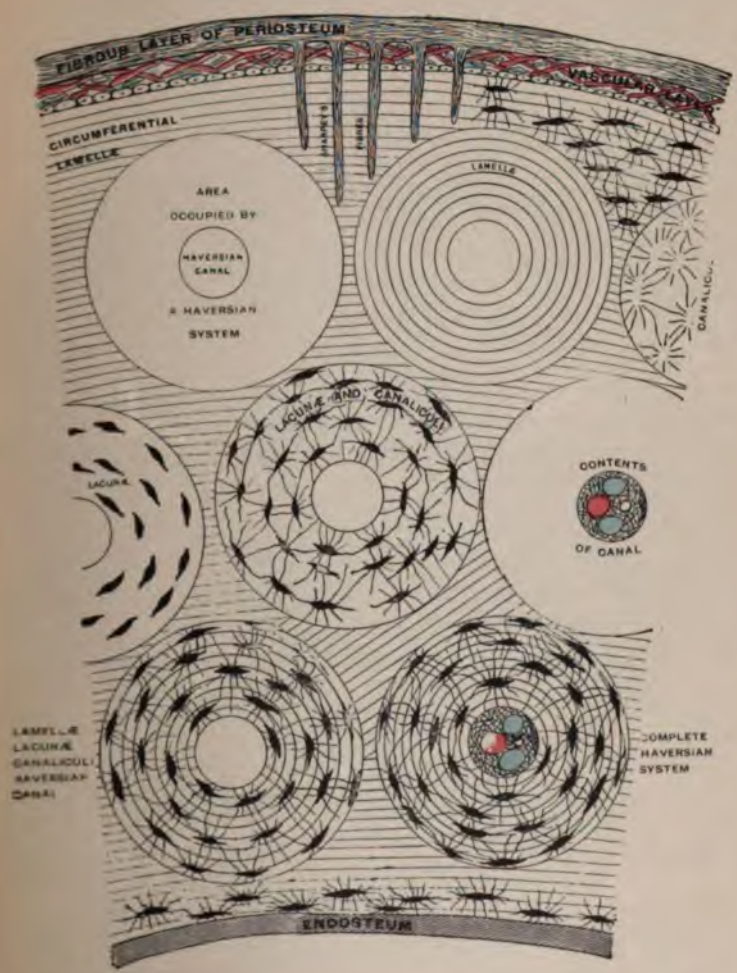


FIG. 16.—Diagram of the structure of osseous tissue. A small part of a transverse section of the shaft of a long bone is shown. At the uppermost part is the periosteum covering the outside of the bone; at the lowermost part is the endosteum lining the marrow-cavity. Between these is the compact tissue, consisting largely of a series of Haversian systems, each being circular in outline and perforated by a central canal. In the first one is shown only the area occupied by a system; in the second is seen the concentric arrangement of the lamellæ; and in the others, respectively, canaliculi; lacunæ; lacunæ and canaliculi; the contents of the canal, artery, vein, lymphatic, and areolar tissue; lamellæ, lacunæ, and canaliculi; and, finally, all of the structures composing a complete system. Between the systems are circumferential and intermediate lamellæ, only a few of which are represented as lodging lacunæ, though it is to be understood that lacunæ are in all parts. The periosteum is seen to be made up of a fibrous layer and a vascular layer, and to have upon its attached surface a stratum of cells. From the fibrous layer project inward the rivet-like fibres of Sharpey. (Gerrish.)


FIBROUS LAYER OF PERIOSTEUM
CIRCUMFERENTIAL LAMELLÆ
AREA OCCUPIED BY A HAVERSIAN SYSTEM
HAVERSIAN CANAL
LAMELLÆ
LACUNÆ AND CANALICULI
LACUNÆ
CONTENTS OF CANAL
LAMELLÆ
LACUNÆ
CANALICULI
HAVERSIAN CANAL
COMPLETE HAVERSIAN SYSTEM
ENDOSTEUM

105. REPAIR OF BONE.—Fracture of a bone is always complicated with more or less injury to the periosteum and other tissues, and with inflammation in the affected area. When tissue is inflamed there is an unusual amount of blood sent to the part, and a consequent exudation of plasma and white corpuscles[1] from the blood into the tissue. When this occurs in bone, a viscid, fibrous tissue called *callus*[2] is formed from substances taken from the plasma which sticks the ends of the bone together. Usually, bone cells—osteoblasts—and lime salts are gradually deposited in this callus, which, consequently, becomes hardened, forming new bone. Excess callus around the point of fracture may be felt, and sometimes seen, as a prominent lump, for some time after the bone has united, but, usually, this is gradually absorbed by the blood, and so removed. Occasionally (especially if the individual's health is poor at the time the fracture occurs) the callus does not ossify. This condition is spoken of as *fibrous union*.

106. Should the periosteum at the point of injury be completely destroyed, the blood supply to the interior of the bone will be so limited that the bone may not be repaired or regenerated.

107. NUMBER AND NAMES OF THE BONES OF THE SKELETON.—There are two hundred bones in the adult human skeleton, exclusive of the three ossicles (small bones) contained in each ear and

[1] Described in paragraphs 462, 463.
[2] Latin *callus*—a hard or thickened skin.

the sesmoid bones embedded in the tendons covering the bones of the hands, knees, and feet. The two hundred bones are situated as follows.

In the skull	22
" " spinal column	24
" " pelvis	4
" " upper extremities	64
" " lower extremities	60
Ribs	24
Os hyoid	1
Sternum	1
	200

108. THE BONES OF THE SKULL.—The skull, which consists of the head and face, contains twenty-two bones—eight in the head or cranium[1] and fourteen in the face.

109. NATURE OF BONES OF THE SKULL.—With a few exceptions (to be discussed later) the bones of the skull belong to the class known as the flat bones. Light weight being more essential than strength for these bones, they are composed largely of cancellous tissue, or of very thin pieces of compact tissue. In most of those of the exterior, the cancellous tissue is covered on both its internal and external surfaces with a thin layer of compact tissue. Certain of these bones, as will be seen in their detailed description, contain hollow spaces—antra[2] and sinuses[3]—which serve two purposes: (1) they make the bones lighter; (2) they act as

[1] Latin *cranium*—the skull.
[2] Latin *antrum*—a cave.
[3] Latin *sinus*—a bend, a hollow.

air chambers. Also, in some of the bones there are foramina for the passage of nerves and blood, and lymphatic vessels to and from the brain.

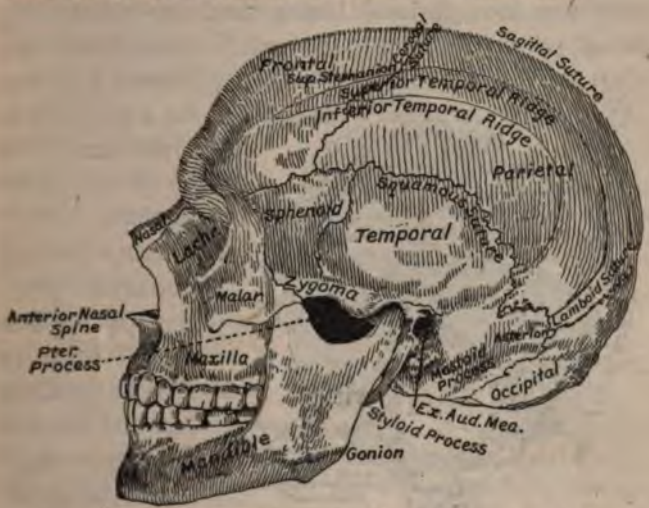


FIG. 17.—Skull, viewed from the left side, showing the principal craniometric points.

110. NAMES OF THE BONES OF THE HEAD OR CRANIUM.—The names of the eight bones forming the cranium are:

Occipital[1]	Frontal[4]
2 Parietal[2]	Sphenoid[5]
2 Temporal[3]	Ethmoid[6]

[1] Latin *occiput*—back of the head. [2] Latin *paries*—a wall.

[3] Latin *tempus*—time. So called because, usually, it is the hair covering the scalp of this part that turns gray first, as the result of age or time. [4] Latin *frons*—the forehead.

[5] Greek *sphen*—a wedge, and *eidos*—form.

[6] Greek *ethmos*—a sieve, and *eidos*—form.

111. THE OCCIPITAL BONE.—This bone forms the back of the skull. It consists of two portions: one, called the squamous (scale-shaped), articulates with the two parietal bones; and the other, the basal portion, extends inward, forming what are known as the *base of the skull* and the *roof of the throat.*

FIG. 18.—The occipital bone, viewed from above.

112. In the posterior portion of the occipital bone is a large opening known as the *foramen magnum* (the great hole) through which nerve-fibers extend between the brain and the spinal canal. On either side of the foramen magnum is a prominent process known as the *occipital condyle.* These condyles articulate with the first bone of the spinal vertebræ and permit of the nodding movements of the head.

113. THE PARIETAL BONES.—The parietal bones, two in number, are situated one on either side at the top of the head. The outer surface of these bones is convex and smooth; the inner, con-

cave and marked by deep depressions and grooves. The former provide space for the convolutions of the brain; the latter form channels for some of the larger vessels in which the blood flows to and from the brain.

114. THE TEMPORAL BONES.—The two temporal bones are situated one on either side of the skull. They each consist of three parts, namely, the squamous,[1] the mastoid,[2] and the petrous.[3] The squamous is the portion which extends from the front of the ear to the cheek. In its lower edge is a depression known as the glenoid[4] or mandibular[5] fossa, into which a condyloid process of the lower jawbone or mandible fits. The mastoid portion is the prominence behind the ear. The lower part of the mastoid is composed largely of cancellous tissue and contains many honeycomb-shaped cavities,

FIG. 19.—The right temporal bone, outer surface. The dotted lines indicate the lines of suture between squamous, mastoid, and tympanic portions.

[1] Latin *squamosus* from *squama*—a scale.
[2] From the Greek *mastos*—the breast, and *eidos*—form.
[3] From the Greek *petra*—a rock.
[4] From the Greek *glene*—a cavity, and *eidos*—form.
[5] From the Latin *mandere*—to chew, masticate.

which communicate with the middle ear. These are called the mastoid cells. They are sometimes the seat of a disease known as mastoiditis, which usually occurs as the result of infection from the middle ear. As the bone at this point is very porous, any suppurative process is exceedingly dangerous, for the infection is likely to travel inward and involve the brain. The petrous portion of the temporal bone is, as the name implies, exceedingly hard. It is situated between the mastoid and the squamous parts at their lower extremity. The inner part of the ears, in which are situated the most essential parts of the organs of hearing, is contained in the petrous portions of the temporal bone.

115. The Frontal Bone.—At birth there are two frontal bones, the bone being divided by a vertical fissure into two lateral halves, but usually the two bones unite in the course of a few years. The single bone thus formed consists of two parts, (1) a vertical or frontal, which forms the forehead, (2) a horizontal portion, which enters into the formation of the roof of the orbits (the cavities which contain the eyes) and the back of the nasal cavity. The vertical portion of the bone articulates at its upper extremity with the two parietal bones, and is bounded at the lower edge by the prominent ridges known as the *supraorbital*[1] *margin*, over which are the eyebrows. Within the

[1] From the Latin *super*—above, and *orbita*—a tract, and *orb*—a ball.

substance of the frontal bone, just above each supraorbital margin, is a hollow space which opens into the nose. These spaces are known as the *frontal sinuses*. They are often the seat of a troublesome infection. In the horizontal part of the bone, in the upper angle of each orbit, is a small depression termed the *lachrymal fossa*, which contains the lachrymal[1] gland, where tears are formed.

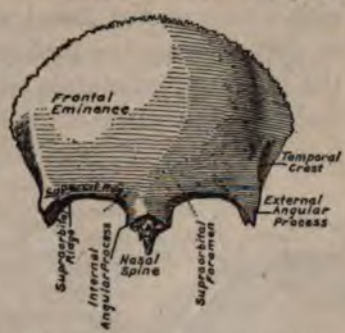


FIG. 20.—The frontal bone, seen from in front.

116. THE ETHMOID.—This is a small, exceedingly light, cancellous bone. It is situated between the two orbits, at the upper part of the posterior wall of the nose, and is joined at the back to the base of the skull. It thus enters into the formation of

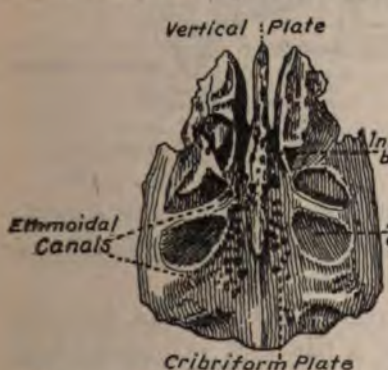


FIG. 21.—The ethmoid bone, seen from above.

[1] From the Latin *lacrima*—tear.

the orbital and nasal cavities and of the base of the skull. Protruding from the ethmoid, on either side of the nasal cavity, are two masses of thin, sponge-like projections of bone known as the superior and middle turbinated[1] bone. In the middle plane of the ethmoid are a number of small foramina through which fibers of the olfactory

FIG. 22.—The sphenoid bone, viewed from above.

nerve pass to the tissues covering the superior turbinated process and the septum—the division between the two sides of the nose.

117. THE SPHENOID.—The shape of the sphenoid bone is that of a bat with extended wings. It is situated immediately behind the ethmoid, to which it is joined, and it articulates also with all the other bones of the skull and with five of those

[1] From the Latin *turbo*—a top. So called because of their twisted shape.

of the face, viz: the two molar, the two palate, and the vomer. It contains several small foramina for the passage of nerves and blood-vessels.

118. THE FONTANELLES AND SUTURES.—Before birth, and for some time afterward, the

FIG. 23.—Fetal skull, side view. Half size. The coronal suture extends from the top of the head downward on either side to the point E; the lambdoidal suture from the back forward, on either side to the point F. The sagittal suture is not shown, but is indicated by the upper margin of the illustration, beginning at the base of the nose, passing backward across the coronal suture (anterior fontanelle), and ending at the lambdoidal suture (posterior fontanelle.)

bones of the skull are united by membrane only, and the membranous spaces between the bones are quite perceptible at the angles formed at the junction of (1) the two parietal and the frontal bones, (2) of the two parietal and the occipital bones, (3) of the lower corners of the parietal bones with the upper corners of the temporal bones. These

spaces are called *fontanelles*,[1] because, especially in the anterior fontanelle—the angle at the junction of the parietal and frontal bones (see Fig. 23)—the pulsations of the brain are visible and were thought, by the early anatomists who named them, to resemble the rise and fall of a fountain. The lateral fontanelles—the four small ones at the side of the head (see Fig. 23)—close soon after birth, and the posterior—that at the junction of the parietal and occipital bones—closes a few months after birth; but the largest one, the anterior, is usually not completely closed until the second year after birth, and sometimes later; occasionally it never closes. The remainder of the membrane between the edges of the bones becomes ossified very soon after birth and the bones firmly united; but, owing to the peculiar formation of their edges, there is a distinct marking along the surface of their articulation, which the early anatomists thought resembled stitches, and therefore named *sutures*.[2]

119. This division of the bones of the fetal skull is of great importance in labor, for it permits of the overlapping of the bones at that time and so diminishes the size of the head, thus facilitating its passage through the mother's pelvis. This process of overlapping is known as *moulding*.

120. Bones of the Face.—The names of the fourteen facial bones are:

[1] French *fontanelle*—a little fountain.

[2] From Latin *sutus*, pf. part. of *suo*—to sew.

Nasal	2
Vomer	1
Inferior turbinated	2
Lachrimal	2
Malar	2
Palate	2
Superior maxillary or maxilla	2
Inferior maxillary or mandible	1

121. THE NASAL BONES.—The nasal bones are the two small oblong bones which form the bridge of the nose.

FIG. 24.—Nasal bone viewed from before.

122. THE VOMER.[1]—The vomer is situated at the lower and back part of the nasal cavity and forms part of the septum[2] which constitutes the central wall of that cavity. The septum is frequently curved to one side, making the nasal chambers of unequal size. This is due to the fragility of the vomer, which, especially in childhood, when it is largely cartilaginous, allows of it being so easily bent that even congestion, due to a cold in the head, can do the bending.

123. THE TURBINATED[3] BONES.—These are two thin, scroll-shaped, cancellous bones which extend horizontally, one on either side, along the outer wall of the nasal fossa.[4] They are below the

[1] Latin *vomer*—a ploughshare.

[2] The front part of the septum consists of cartilage.

[3] From the Latin *turbo*—a top.

[4] The nasal fossæ are two irregular cavities situated one on

superior and middle turbinated bones, which, it will be remembered, are processes of the ethmoid. The inferior turbinated bones articulate with the ethmoid, the superior maxillary, the lachrymal, and the palate bones. Hypertrophy and other abnormal conditions of the turbinated bones and the membrane covering them constitute some of the more common nasal diseases.

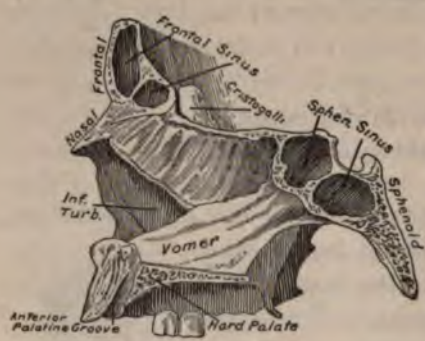


FIG. 25.—Sagittal section of face, a little to the left of the middle line, showing the vomer and its relations.

124. THE LACHRYMAL[1] BONES. — These are two small, exceedingly thin bones, situated one on either side of the nose, between it and the orbital cavities. They are so-called be-

FIG. 26.—Right inferior turbinate bone, external surface.

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either side of the face, at the back of the nose. Their anterior margins, the openings into the nose, are spoken of as the anterior nares, and the posterior, which open into the pharynx—part of the throat—as the posterior nares.

[1] From the Latin *lacrima*—a tear.

cause they contain part of the canal through which the lachrymal tear-duct runs.

125. THE MALAR[1] BONES.—The malar bones form the prominences of the cheeks and part of the floor and outer wall of each orbital cavity. They articulate at their posterior border with a process of the temporal bones and by so doing form what is known as the *zygomatic*[2] arch.

FIG. 27.—Right lachrymal bone inner surface.

126. THE PALATE[3] BONES. — These two bones are each shaped like an L. They constitute the back part of the roof of the mouth, part of the floor and outer walls of the nasal fossa, and of the floor of the orbits.

FIG. 28.—Right malar bone.

127. THE SUPERIOR MAXILLARY[4] BONES.—These bones usually unite before birth forming practically one bone known as the maxilla or upper jawbone,[5] which constitutes the greater part of

[1] From the Latin *mala*—the cheek.
[2] From the Greek *zygos*—yoke.
[3] From the Latin *palatum*—palate.
[4] From the Latin *maxilla*—jaw.
[5] When it fails to do so, the condition is known as cleft palate.

the roof of the mouth, part of the floor and outer wall of the nasal fossa, and part of the floor of the orbits. The lower anterior process of the bone is called the *alveolar*[1] *process* and in it are the depressions into which the roots of the upper teeth fit. The two upper anterior extremities of the bone are hollow and the cavities, called the *antra of*

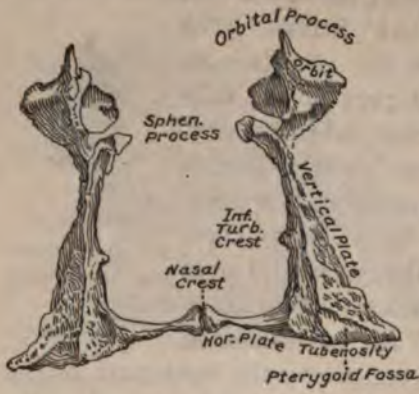

FIG. 29.—The two palate bones in their natural position, dorsal view.

FIG. 30.—Superior Maxillary bone and the bony sinuses of the head. (Gerrish.)

Highmore, open one on either side into the nasal chambers. These antra are very frequently the

[1] Alveolar. From the Latin *alveolus*—a little hollow.

seat of a troublesome infection, the usual source of which is abnormal conditions of either the nose or teeth.

FIG. 31.—The right half of the mandible, inner surface. (Gerrish.)

128. THE INFERIOR MAXILLARY OR MANDIBLE BONE.—This is the only movable bone in the skull. It consists of a curved horizontal body with a thickened border called the *alveolus*, which contains the lower teeth, and an upright branch on each side, the ramus,[1] which is attached by means of ligaments to a temporal bone. On the upper end of each

FIG. 32.—The Hyoid bone. Viewed from the left and in front. (Gerrish.)

[1] Latin *ramus*—a branch. Plural *rami*.

ramus is a condyloid process which enters into articulation with the temporal bone.

129. THE HYOID.[1]—Bone of the Neck.—The hyoid is a U-shaped bone situated in the neck just above the cartilaginous prominence known as *Adam's apple*. It does not articulate with any other bones, but is suspended from a process of each temporal bone by ligaments and muscles. It serves to support the tongue, which is attached to it by muscles.

130. THE TRUNK OR TORSO.—The trunk consists of the thoracic, abdominal, and pelvic cavities. The bones which form its framework are those of the spine, the ribs, the sternum, and the pelvis.

The Spinal or Vertebral Column

131. NUMBER OF BONES CONSTITUTING THE COLUMN.—In youth the spine consists of thirty-three irregular bones called *vertebræ*. Early in life, however, the nine bones at the lower end of the column become ossified so that they form but two bones, the upper five uniting to form what is known as the *sacrum*, and the remaining four, the *coccyx*. Thus, for the greater part of life the spine consists of:

24 vertebræ proper
1 sacrum
1 coccyx

[1] Greek *hyoeidos*—the hyoid bone, so called from its shape.

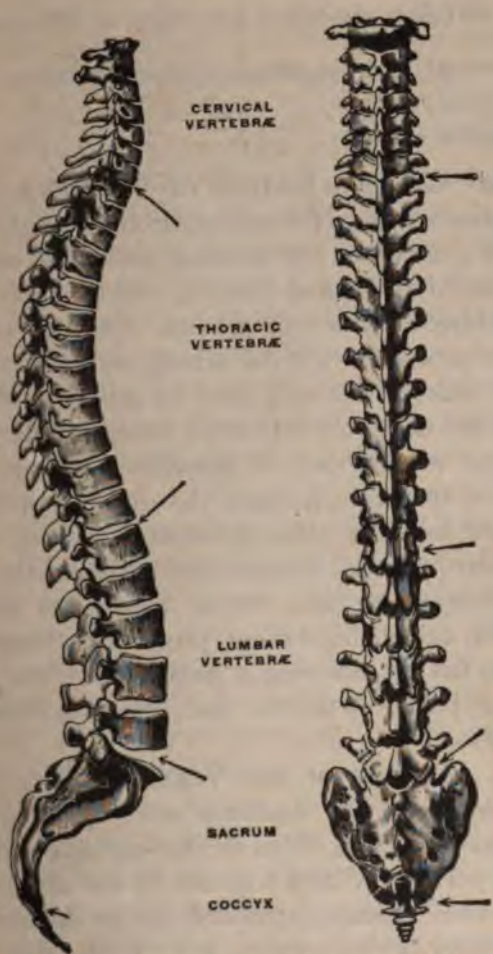

FIG. 33.—The spinal column, right lateral view and dorsal view. (Gerrish.)

The vertebræ are called according to their location:

Cervical (neck) vertebræ, of which there are						7
Thoracic (chest)	"	"	"	"	"	12
Lumbar (groin)	"	"	"	"	"	5

132. General Nature of Vertebræ.—Each vertebra consists of a solid portion called the body, which constitutes the anterior and more compact portion of the spinal column, and an arch. The two united form a ring of bone. On each arch are seven processes, two of which, situated one on either side of the arch near its junction with the body, are called the *transverse processes*—they serve for the attachment of muscles; the next four, situated two on each side of the arch, one projecting upward and the other downward, are called the *articular processes*, because they articulate with the vertebræ above and below them; the seventh process, called the *spinous*, projects backward and can be felt by drawing a finger down the center of the back; it serves for the attachment of muscles.

133. Nature of the Vertebral Column.—The *bodies* of the vertebræ are piled one upon another with thick disks of fibro-cartilage between them. They are held together by the articulation of (1) their articular processes, (2) by the cartilaginous disks between them, and (3) by semi-elastic ligaments, and form a strong but flexible column. The interior of the column is hollow and is termed the *spinal canal*. It contains the spinal cord. Be-

tween each pair of vertebræ are apertures through which the spinal nerves pass from the cord.

134. Curves of the Spinal Column.—A glance at the vertebral column shows that it is not a straight vertical pillar, but that it has four decided curves: one at the neck, rounding convexly slightly forward; a second in the thorax curving convexly slightly backward; a third in the lumbar region, in which the convexity of the curve is very decidedly forward—this forms the hollow known as the *small of the back;* the fourth is that of the sacrum and coccyx, and, as its convexity is backward, it serves to increase the size of the pelvic cavity very considerably.

135. Purpose of Curves and the Cartilage Pads.—The curves of the spinal column add to its strength and elasticity and thus increase its resistance to injury, and prevent jarring of the spinal cord and brain. The pads of fibro-cartilage between the bodies of the vertebræ serve the same purpose; these also, as previously stated, serve to hold the vertebræ together.

136. Abnormal Curves.—Pathological exaggerations of the spinal curves may exist, either as the result of injury or disease. Exaggerated curves are often spoken of as *curvatures of the spine;* and if the curve is lateral, *i. e.*, toward one side, it is called scoliosis[1]; if dorsal, kyphosis (humpback); and if ventral, *i. e.* forward, lordosis.[2]

[1] From the Greek *scolios*—crooked.
[2] From the Greek *lordos*—bent supinely.

137. Spina Bifida.—Another abnormal condition that occasionally occurs in the structure of the spinal column is a lack of proper development of the arch of some of the vertebræ, in consequence of which there will be at birth a protrusion of the spinal meninges[1] through the resulting aperture. This condition is known as *spina bifida.*

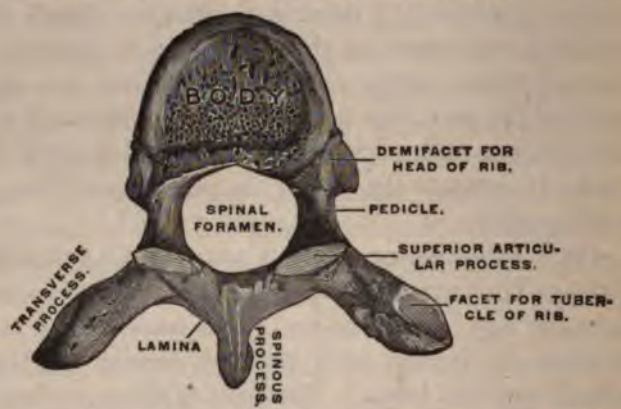

Fig. 34.—A thoracic vertebra, upper surface. (Gerrish.)

138. Variation in the Shape of the Vertebræ in Different Parts of the Spine.—The vertebræ are not all exactly the same size or shape. The bodies of the five lumbar vertebræ are larger and stronger than those of the thoracic and cervical. Those of the thoracic are larger than the cervical, and they contain depressions which receive the vertebral ends of the ribs. The arches of the cervical vertebræ are larger than those of the other

[1] The membranes covering the spinal cord and brain.

two regions, but their spinous processes are shorter and some of them are bifid, *i. e.*, split in two. The two upper cervical vertebræ, known as the atlas[1] and axis,[2] differ from all others. The atlas—the uppermost one—has a depression on either side into which the condyloid processes of the occipital bone fit; thus it supports the head. The atlas has neither a body nor spinous processes and is practically a bony ring. A strong ligament is stretched transversely across the interior of this ring, dividing it into two sections, a posterior and an anterior. The former serves as a passage for the spinal cord, and the latter receives a process which projects upward from the axis. This process, called on account of its shape, the odontoid,[3] acts as a pivot around which the atlas and with it the skull can rotate. It is retained in position and prevented

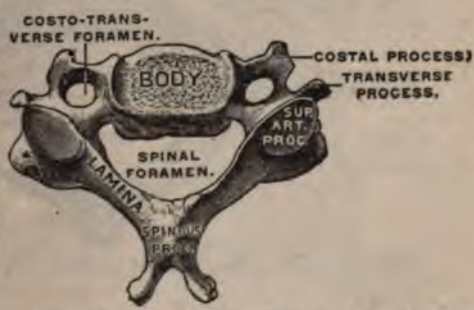

FIG. 35.—Cervical vertebra, viewed from above. (Gerrish.)

[1] So called because it supports the head, after a giant of mythology who was supposed to support the world on his shoulders.

[2] Latin *axis*—an axle. The pin on which a body turns.

[3] From the Greek *odontos*—a tooth, and *eidos*—form.

from pressing on the spinal cord by the transverse ligament of the atlas. A hard fall on the head is likely, either by dislocating the atlas on the axis or by fracture of the odontoid process, to cause the latter to press upon the spinal cord and result in instant death. Such an injury is commonly known as a *broken neck.*

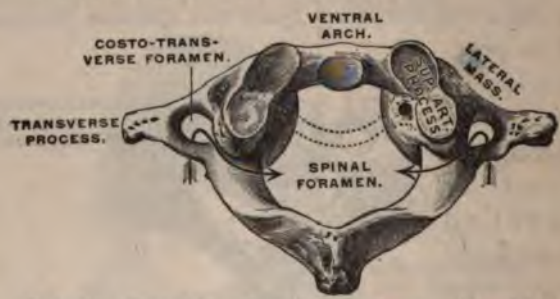

FIG. 36.—The atlas, viewed from above. (Gerrish).

The Thoracic Cavity

139. The bony framework of the thoracic[1] cavity is formed by the sternum,[2] the ribs, and the thoracic vertebræ of the spine.

140. THE STERNUM.—The sternum or breastbone is a thin, flat, narrow bone, about, in the adult, six inches long, situated in the median line of the anterior chest wall. It consists of three parts, named the *manubrium* or *handle*, the *gladiolus* or *blade*, and the *ensiform* or *sword.*[3] In youth these

[1] From the Greek *thorax*—a breastplate.

[2] Latin *sternum*—the breast bone.

[3] These names were given to the different parts of the sternum because it was thought to be shaped like a sword.

three parts are united by cartilage and ligaments only, and the ensiform is entirely cartilaginous, but later ossification takes place and the three parts are firmly united as one bone; the lower end of the ensiform, however, remains cartilage. On either side of the handle and blade are notches for articulation with the sternal ends of the ribs. The ensiform has no articulation with the ribs, but it affords attachment for the abdominal muscles.

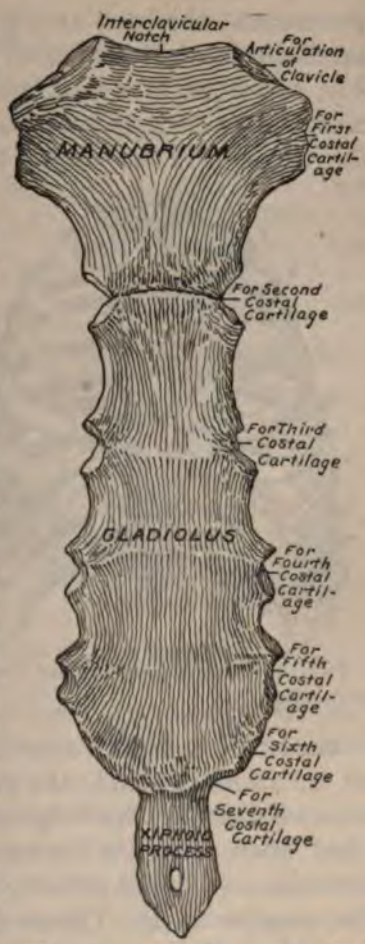

FIG. 37.—The sternum, ventral aspect.

141. THE RIBS.—The ribs, twenty-four in number, are situated twelve on each side of the thoracic cavity. The upper seven, called the true ribs, articulate with the upper seven thoracic

vertebræ at the back and, by means of the costal cartilages, with the sternum in front. The lower five, called the false ribs, are attached to the vertebræ in the back, but they are not connected with the sternum. The upper three pairs, viz: the eighth, ninth, and tenth, are each attached to the costal cartilage of the rib next above it. The two remaining ribs are unattached in front, and are therefore called *floating ribs*. The spaces between the ribs are called *intercostal spaces*.

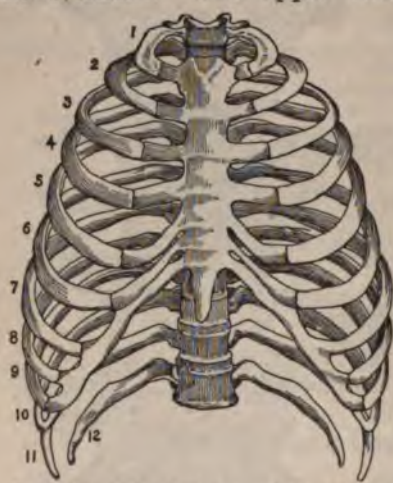

FIG. 38.—The skeleton of the thorax, front view.

142. It will be noticed that the front attachments of the ribs are all cartilaginous, and, the costal cartilages being somewhat elastic, this helps in the expansion of the chest when certain of the muscles covering the ribs contract, and in the relaxing of the chest walls, as the muscles relax. This action will be again referred to in the chapter devoted to the respiration.

143. THE BONES OF THE UPPER EXTREMITIES —Number.—There are thirty-two bones in each of the upper extremities, thus:

In the shoulder girdle	clavicle	1
	scapula	1
" " arm	humerus	1
" " forearm	ulna	1
	radius	1
" " wrist	carpus	8
" " hand	metacarpus	5
	phalanges	14
		32

144. THE SHOULDER GIRDLE.—The two clavicles, or collar-bones, and the two scapulas, or

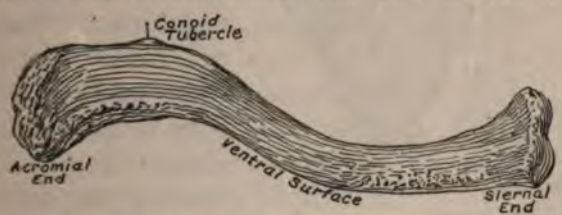

FIG. 39.—The right clavicle, upper surface.

shoulder-blades, together form what is known as the *shoulder girdle*, which serves to connect the upper extremities with the trunk.

145. THE CLAVICLE[1] OR COLLAR-BONE.—The clavicle is a long bone, but, unlike the typical long bones, it has no medullary canal. It is slightly curved, the curve being more pronounced and the bone thicker in men than in women. It is placed horizontally across the upper part of the thorax, articulating at its inner extremity

[1] From the Latin *clavis*—a key.

with the sternum—to which it is held in apposition with strong anterior and posterior ligaments—and at its outer end with the acromion[1] process of the scapula.

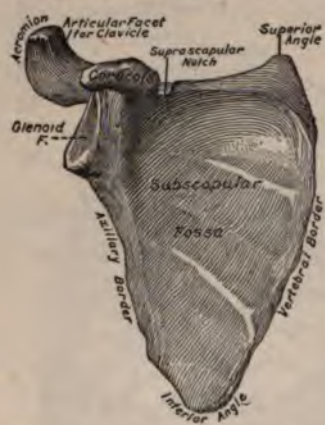

FIG. 40.—The right scapula, ventral view.

146. THE SCAPULA[2] OR SHOULDER-BLADE.—The scapula is an irregular triangular-shaped bone, placed on the dorsal surface of the thorax between the first and eighth ribs. The upper third of the posterior surface of the bone is crossed by a sharp ridge called the *spine of the scapula*, which terminates in a prominent projection called (because it forms the summit of the bone) the *acromion*[1] *process*. Below and in front of the acromion process is the *coracoid*[3] *process*, and under these two processes, which serve for the attachment of some of the muscles holding the arm in place, is the *glenoid*[4] *cavity*, into which the head of the humerus—arm-bone—fits.

[1] From the Greek *akron*—the summit.

[2] Latin *scapula*—the shoulder-bone.

[3] From the Greek *korakos*—a crow, and *eidos*—form. The process was so named because it was thought to be the shape of a crow's beak. [4] From the Greek *glene*—a cavity, and *eidos*—form.

147. THE HUMERUS.[1]—The humerus, which is the arm-bone, may be said to consist, like all long bones, of a shaft and two extremities; the shaft being the straight, central portion and the extremities the broader, irregular portions at either end. The upper extremity of the humerus consists of a hemispherical prominence called the *head*, which fits into the glenoid cavity; a constricted portion known as the *anatomical neck*, and two prominences, one on either side of the bone, called the *greater* and the *lesser tuberosities*. Below the tuberosities, at the beginning of the shaft, is a slight constriction known as the *surgical neck* because it is so frequently fractured. At its lower extremity the humerus becomes flattened from before backward and is divided in the center by a small indenture, so that it ends in two rounded prominences known as the *inner* or *medial condyle* and the outer *condyle*. These help to form the elbow joint. Between the two condyles is what is known as the articular surface, the medial part of which, called the *trochlea*, fits into a depression in the upper end of the ulna, and the smaller, outer part, called the *capitellum*, fits into a depression in

FIG. 41. — The humerus, or arm-bone.

[1] Latin *humerus*—the shoulder.

the radius. Just above the trochlea are two small depressions which receive the front articulating processes of the ulna and radius when the forearm is bent.

148. THE ULNA.—The ulna[1] or elbow-bone is—with the figure in the anatomical position (paragraph 34)—the inner bone of the forearm. It is thicker and longer than the radius. On the end of its upper extremity are two rather flat, curved processes; the one on the back of the bone, which is the larger of the two, is called the *olecranon*[2]; the one on the front surface is termed the *coronoid*[3]; between the two is a depression into which the trochlea of the humerus fits. On the outer side of the coronoid[3] process is a depression—the *lesser sigmoid cavity*—into which the head of the radius fits. The lower extremity of the ulna ends in two prominences; the outer one, called the *head*, articulates with the radius; the inner one, known as the *styloid*[4] process, serves for the attachment of ligaments from the wrist; but the ulna does not articulate with any of the wrist bones.

149. THE RADIUS.—The radius is on the outer or thumb side of the forearm, parallel with the ulna. On its upper extremity is a cylindrical prominence—the *head*—in the top of which is a shallow depression to receive the capitellum of the

[1] From the Greek *olene*—elbow.
[2] From the Greek *olene*—the elbow, and *kranon*—the head.
[3] From the Greek *korone*, meaning anything hooked or curved.
[4] From the Greek *stylos*—a pillar, and *eidos*—form.

humerus, and around which is a ridge that moves in the lesser sigmoid cavity of the ulna when the radius, and with it the hand, is rotated—turned. Below the head is a constricted portion—the *neck*

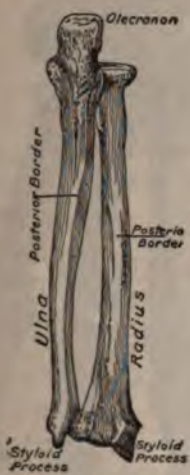

FIG. 42.—The bones of the right forearm, dorsal view.

FIG. 43.—The bones of the right forearm, ventral view.

—and a tuberosity for the attachment of muscles. The lower extremity of the radius is wider than the upper. On its inner surface is a shallow depression into which the head of the ulna fits. Its lower edge is concave and articulates with two of the bones of the wrist. At its outer edge is a process called (like that of the ulna) the *styloid*.

150. CARPUS[1] OR WRIST.—The wrist is com-

[1] From the Greek *karpos*—the wrist.

posed of eight small, *short* bones, arranged in two rows, one below the other, and held together with

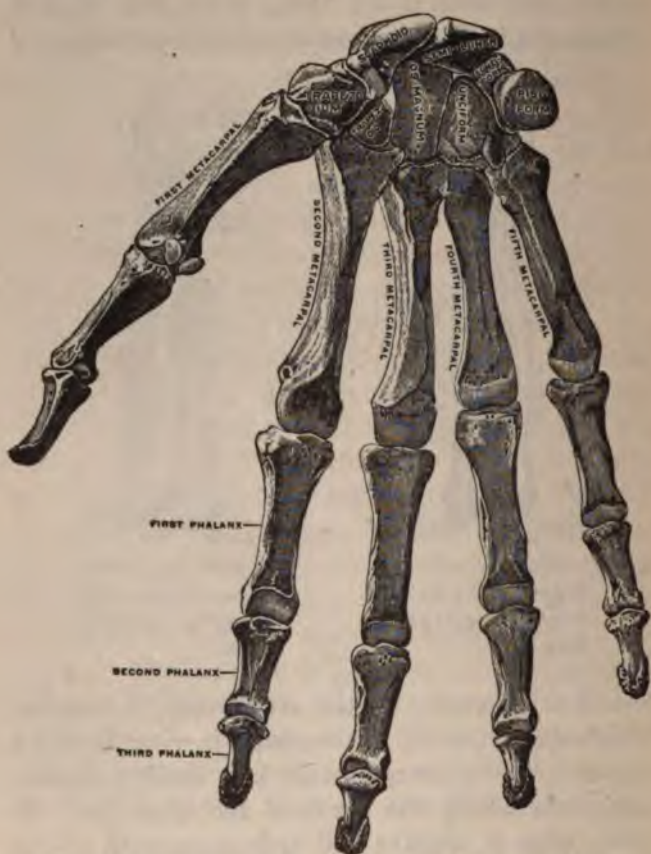

FIG. 44.—The bones of the right hand, palmar aspect. (Gerrish.)

ligaments. They are named from their shape as follows:

First row:

Scaphoid. Greek, *skaphe*—boat, and *eidos*—form.
Semilunar. Latin, *semi*—half, and *luna*, moon.
Cuneiform. Latin, *cuneus*—wedge.
Pisiform. Latin—*posum*—pea, and *forma*—likeness.

Second row:

Trapezium. Greek, *trapezion*—a table.
Trapezoid. Greek, *trapezion*—a table, and *eidos*—form.
Os magnum. Latin, *os*—bone, and *magnum*—large.
Unciform. Latin, *uncus*—a hook, and *forma*—likeness.

151. THE METACARPUS OR BONES OF THE PALM OF THE HAND.—The skeleton of the palm of the hand consists of five cylindrical bones. Like the long bones, the metacarpal bones have a shaft and two extremities, but they have no medullary canal. They are slightly convex on their back surface and concave on their inner. They articulate at their base with the lower row of carpal[1] bones and with each other, and at their heads with the first row of phalanges.[2]

152. THE PHALANGES.—The phalanges are the bones of the fingers and thumb. There are three in each finger and two in the thumb, making fourteen in each hand. The first row articulates with the metacarpal bones; the second with the first row of phalanges, and the third with the second row.

[1] Same as *carpus*.
[2] From the Latin *phalanx*—a line of soldiers.

The Pelvis

153. BONES OF THE PELVIS.—The pelvis,[1] so called from its supposed resemblance to a basin, is composed of four bones, viz:

2 ossa innominata[2]; these constitute the two hip bones;
1 sacrum of the vertebral column;
1 coccyx " " " "

FIG. 45.—Female Pelvis.

In youth each os innominatum consists of three bones, and though in the adult the three are welded into one, the bone is, for convenience in description, usually spoken of as consisting of:

The ilium[3] (plural ilia)
The ischium (plural ischia)
The pubis[4] (plural pubes)

[1] Latin *pelvis*—a basin.

[2] From the Latin *ossa*—bones, and *innominata*—unnamed. These bones were so called because their shape did not resemble that of any known object.

[3] Greek *ilium*—a citadel.

[4] From the Latin, *pubes*—hair. So called because the skin covering these bones, at the time of puberty, becomes covered with hair.

154. THE ILIA.—The ilia are the two large bones which, with the sacrum (with which they articulate at the back), form the back and sides of the pelvis. The upper expanded portion of each ilium, called the wing, constitutes the side wall of what is known as the false pelvis, and also the prominence of the hip. The ridge, or upper border of the wing, is called the *crest of the ilium*, and the anterior extremity of the crest is known as the *anterior superior spine of the ilium*.

155. THE PUBES.—The two pubic bones form the front wall of the pelvis. They are held together in the front median line with strong cartilage, the point of articulation being known as the *symphysis*[1] *pubis*. They are connected with the ilia at their posterior end, and with the ischia at their lower border. At the place of union of the three bones is a deep cup-shaped depression, called the *acetabulum*,[2] into which the head of the femur—the thigh-bone—fits. Between the central portion of the ischium and pubic bone is a large hole called the *obturator foramen*.

156. FALSE AND TRUE PELVIS.—As can be seen by looking at Fig. 45, the upper part of the pelvis flares and is larger in every way than the more constricted lower portion, and the change in shape takes place so suddenly that there is a decided marking line between the two parts. The upper flaring portion is known as the *false*

[1] Greek *symphysis*—growing together.
[2] Latin *acetabulum*—concave, depressed.

pelvis, and it constitutes the posterior support of the abdominal cavity. The dividing line is known as the *brim of the true pelvis*, and also as the *superior strait of the pelvis*. The constricted portion below the brim is termed the *true pelvis*. It contains the internal organs of generation, the rectum, and the urinary bladder. The upper opening of the true pelvis, *i. e.*, the space between the brim, is called the *inlet* of the *pelvis*, and the opening at the bottom of the pelvis is known as the *inferior strait* and *outlet* (see Fig. 45).

157. Differences between the Female and Male Pelvis.—Comparing the female with the male pelvis, we find that the former is so modified that it is especially adapted for pregnancy and parturition. It is more shallow than the male pelvis, but wider and more capacious, the coccyx is more movable, the inlet and outlet larger, and the bones lighter and smoother.

Bones of the Lower Extremities

158. Number of Bones.—In addition to the ossa innominata, which enter into the formation of the hip-joint, as well as that of the wall of the pelvic cavity, there are thirty bones in each of the lower extremities.

159. The Pelvic Girdle.—The bones of the pelvis, especially when spoken of in connection with the lower extremities, are often referred to as the *pelvic girdle*, and they are to the lower extremi-

ties what the bones of the shoulder girdle are to the upper, viz., the connecting link between the extremities and the trunk.

160. NAMES OF BONES.—The names of the bones in each of the two lower extremities are:

In the thigh	the femur	1
" " knee	the patella	1
" " leg	the tibia	1
	the fibula	1
" " ankle	the tarsus	7
" " foot	the metatarsus	5
" " toes	the phalanges	14
		30

161. In their shape, markings, and articulations, the bones of the lower extremities are very similar to those of the upper, but they are much stronger and larger. The thigh bone and the bones of the leg comprise, like those of the arm and forearm, an upper and lower extremity and a shaft, with prominences and depressions for articulation, and prominences and grooves for the attachment of muscles.

162. THE FEMUR[1].—This is the longest, largest, and strongest bone in the body. When a person is in the erect posture the femur is not vertical, being separated from its fellow above by the whole breadth of the pelvis, but inclining gradually

[1] Latin *femur*—the thigh.

FIG. 46.—The right femur, rear view. (Gerrish.)

downward and inward, so as to approach its fellow toward its lower part, for the purpose of bringing the knee-joint near the line of gravity of the body. The degree of this inclination varies in different individuals, and is greater in women than in men, on account of the greater width of the pelvis in the former. The upper extremity of the femur consists of (1) a large spherical tuberosity called the *head*, which fits into the acetabulum of the innominate bone of the pelvis, (2) a constricted portion called the *neck*, which connects the head with the shaft, and (3) two large tuberosities, one at each side, at the junction of the neck and shaft, called the *greater* and

lesser trochanter.[1] These trochanters afford attachment for the muscles which allow of the rotation of the thigh. At its lower extremity the femur is flattened from before backward, and divided into two processes called the *internal* and *external condyles.* The condyles are continuous in front and present a smooth concave surface which articulates with the patella.

163. THE PATELLA[2] OR KNEE-CAP.—This is a flat, triangular bone situated in front of the knee-joint which it serves to protect. It articulates, as stated in the preceding paragraph, with the two condyles of the femur. It is developed in tendon and, on account of this and its shape is called a sesmoid bone (paragraph 94).

FIG. 47.—The right patella, dorsal surface. (Gerrish.)

164. THE TIBIA OR SHIN BONE.—Next to the femur, the tibia[3] is the largest bone in the body. It is situated in the front and inner side of the leg. The upper extremity or head is large and expanded into two tuberosities, in each of which is

[1] From the Greek *trochao*—to turn.
[2] From the Latin *patera*—a dish, a pan.
[3] Latin *tibia*—a pipe, the shin bone.

FIG. 48.—The right tibia and fibula in their normal relations, rear view. (Gerrish.)

a concave depression for articulation with the condyles of the femur. The lower extremity is much smaller than the upper, and is prolonged downward on its inner side into a strong process, the *inner* or *medial malleolus*, which serves for the attachment of ligaments of the ankle and, being concave on its inner surface, enters into the articulation with the astragalus, one of the large

bones of the ankle. The tibia articulates also with the fibula.

165. THE FIBULA OR CALF BONE.—The fibula,[1] a much more slender bone than the tibia, extends parallel with it, but on the outer side of the leg. On its upper extremity is a slight depression which articulates with the external tuberosity of the tibia, and a pointed process — the styloid. The lower extremity of the fibula ends in a prominent process, convex on its outer surface and concave on its inner, the external malleolus, which affords attachment for ligaments of the ankle and articulates with the outer surface of the astragalus.

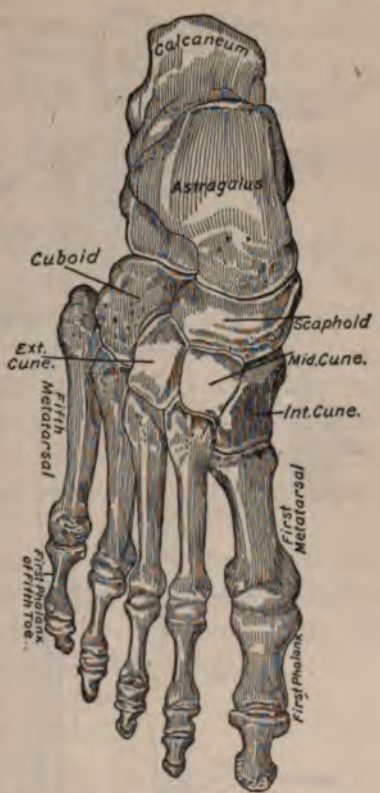

FIG. 49.—The bones of the right foot, viewed from above.

[1] Latin *fibula*—a buckle, a clasp.

166. TARSUS BONES.—There are seven tarsus[1] bones, viz:

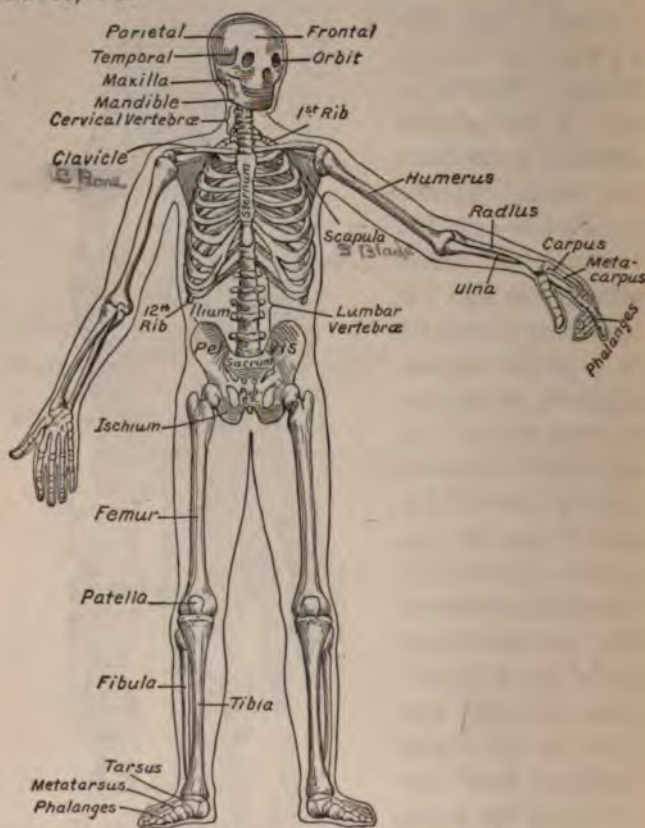

FIG. 50.—The Human Skeleton.

Calcaneum or os calcis. Latin *calx*—the heel;

Astragalus. Greek *astragalos*—the ball of the ankle;

[1] Tarsus. From the Latin *tarsos*—the instep.

Cuboid. Greek *kubos*—a cube, and *eidos*—shape;
Scaphoid. Greek *skaphe*—a boat, and *eidos*—form;
Internal cuneiform. Latin *cuneus*—a wedge, and *forma*—form;
Middle cuneiform. Latin *cuneus*—a wedge, and *forma*—form;
External cuneiform. Latin *cuneus*—a wedge, and *forma*—form.

167. Of these the calcaneum and the astragalus are the two largest; the former constitutes the heel bone, and the latter, as it supports the tibia and articulates with both tibia and fibula, is an important factor in the movements of the ankle.

168. THE METATARSUS BONES.—There are five metatarsus bones. Their shape and mode of attachment are similar to those of the metacarpus of the hand.

169. THE PHALANGES.—The phalanges of the toes, both in number and general arrangement, resemble those of the hand, there being two in the large toe, and three in each of the others.

CHAPTER V

THE JOINTS OR ARTICULATIONS—THE TEETH

Different Kinds of Joints. Names and Nature of Each Variety. Synovitis. Bursitis. Sprains. Dislocations.

THE TEETH: Location. Names of Various Parts. Nature of Tooth Substance. Structure. Different Kinds of Teeth. Temporary and Permanent Teeth: Their Number, Nature, and Time of Eruption. Development of the Teeth.

The Joints

Each of the bones constituting the skeleton, except the hyoid, is connected to one or more of the other bones, and the connected surfaces are spoken of as joints or articulations.

170. DIFFERENT KINDS OF JOINTS.—The articulations are classified according to the amount of movement of which they are capable, as:

1. Immovable joints.[1]
2. Slightly movable joints.[2]
3. Freely movable joints.[3]

171. IMMOVABLE JOINTS.—The surfaces of ar-

[1] Also called synarthrosis. [2] Known also as amphiarthrosis.
[3] Or diarthrosis.

ticulation of the bones of the head and of the face, except the lower jaw, are of this type.

172. NATURE OF THE IMMOVABLE JOINTS OF THE SKULL.—The articulating surfaces of the bones are applied in almost close contact, being separated only by the interposition of a thin layer of fibrous membrane, the sutural ligament, and, in certain situations at the base of the skull, a thin layer of cartilage. The bones are held together as well as separated by cartilage and fibrous tissue, and the majority of the bones of the head are held in apposition also by the tooth-like processes along their edges, the processes of each bone interlocking with those of the one with which it articulates.

173. SUTURES.—The surfaces of the joints formed by this interlocking of processes have somewhat the appearance of sewed seams and were therefore named *sutures*.

174. SLIGHTLY MOVABLE JOINTS.—The principal examples of the slightly movable joints are the articulations (1) between the bodies of the vertebræ of the spinal column; (2) between the two pubic bones—the *symphysis pubis;* (3) between the ilia and the sacrum—the *sacro-iliac articulation.*

175. NATURE OF ARTICULATION IN THE SLIGHTLY MOVABLE JOINTS.—In this form of articulation the surfaces of the contiguous bones are either connected by pads of fibro-cartilage which adhere to the end of each bone, as in the

articulation between the bodies of the vertebræ, or else the articulating surfaces are covered with fibro-cartilage, partially lined with synovial membrane and connected by external ligaments, as in the sacro-iliac articulation and symphysis pubis. Both these forms are capable of limited motion. The motion between the pubic articulations is, in women, very much increased during parturition, certain of the ligaments holding the bones together becoming considerably softened during pregnancy. This increased power of movement facilitates, in fact is essential for, the normal birth of a child.

176. Nature of the Articulation of the Vertebral Column.—All of the articulations in the vertebral column do not belong to the type just described; as will be seen later, the articulations between the articulating processes of the arches are of the freely movable gliding-joint type and, as can be seen by examining the skeleton, the arches of the vertebræ are not superimposed upon each other in the same compact manner as the bodies. This arrangement, as well as the elastic nature of the intervertebral pads of cartilage and of the ligaments of the spine, allow of the bending and other free movements of the spine. Also, the arrangement of the ligaments is particularly adapted to free motion. It is as follows: On the anterior and posterior surfaces of the bodies—the latter being of course within the spinal canal—the ligaments extend as long, strong, but elastic bands, from the axis to the sacrum; and the short,

thin, elastic ligaments holding the arches together, extend but from arch to arch. As age advances, the ligaments lose their elasticity and movement of the spine is much more limited.

177. Nature of the Freely Movable Joints.—In the freely movable joints the bones forming the articulation are generally, for the greater convenience of their mutual connection, expanded at their surfaces of apposition, and the articulating part of the extremity of one bone is concave and that of the other convex, so that they fit into each other. The articulating surfaces are covered with smooth hyaline cartilage and held together by strong ligaments or capsules of fibrous tissues, and lined with a membrane called the *synovial membrane*, which secretes a fluid to lubricate the various parts of the joint and thus prevent friction between the moving surfaces. This membrane, which will be further described in Chapter X, connects with the cartilage between the articulating surfaces and lines the ligaments holding the bones in apposition, so that with the cartilage it completely encloses, or encapsulates, the joint. See Fig. 51.

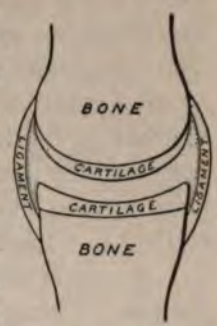

Fig. 51.—Diagram of articular synovial membrane. The cartilages are represented as drawn apart for the sake of clearness. The synovial membrane is shown by a broken line. (F. H. G.)

178. Bursæ.—In addition to the synovial

membrane lining the joint, as described in the last paragraph, there are flat sacs of similar membrane placed over such prominent parts of joints as the patellàs, the malleoli, the olecranons, the knuckles, etc. These sacs are called *bursæ*.[1] The membrane composing them secretes a fluid, so that normally they always contain a slight amount of fluid, which serves to prevent friction between the bone and the ligament, tendon, or skin moving over it. Bursæ will be further described in Chapter X.

179. Different Kinds of Freely Movable Joints.—Though the foregoing description is true in the main of all the freely movable joints, there is considerable difference in the character of the joints placed under this heading; therefore the class has been subdivided and, according to the nature of their structure or of their movement, the joints belonging to this variety have been classed as:

1. Ball-and-socket joints.
2. Condyloid joints.
3. Hinge joints.
4. Pivot joints.
5. Saddle joints.
6. Gliding joints.

180. Ball-and-Socket Joints.—The hip and shoulder joints are of this type. They consist of a large rounded head which fits into a cap-shaped

[1] Bursa. Latin, a bag.

depression and is held in place with strong non-elastic ligaments, the surrounding muscles, and, especially in the case of the shoulder joints, atmospheric pressure. Such joints are freely movable in all directions, the shoulder joint being the most freely movable articulation in the body.

181. CONDYLOID JOINTS.—In this form of joint an ovoid articular head, or condyle, is received into an elliptical cavity in such a manner as to permit of the movements known as flexion and extension, abduction and adduction, and circumduction, but not rotation. Examples of condyloid joints are the wrists and the articulations of the metacarpal and the metatarsal bones with the phalanges.

182. HINGE JOINTS.—In hinge joints the bones are held in apposition chiefly by strong lateral—side—ligaments which permit of motion in two directions only, viz. backward and forward, *i. e.*, flexion and extension. The most perfect examples of hinge joints are the elbows and the articulations between the phalanges; the knee and ankle joints are also of this type, but in some positions they allow of other movements than flexion and extension. The rotary movements of the forearm which appear to take place in the elbow occur, in reality, in the articulation between the radius and ulna.

183. PIVOT JOINTS.—Pivot joints are those in which one bone rotates around another, the latter remaining stationary. Examples of this

form of joint are: (1) that between the axis and atlas, in which the atlas, and with it the skull to which it is attached, turns around the odontoid process of the axis; (2) the articulation between the head of the radius and lesser sigmoid cavity of the ulna. By virtue of this articulation, when the hand is turned, the radius, which articulates with certain of the carpal bones, rotates around the ulna, the latter remaining stationary.

184. Saddle Joints.—The best example of this form of joint is that between a metacarpus of the hand and the first phalanges of the thumb. This kind of joint was so named because when one bone is extended from the other, as the thumb from the hand, the shape of the angle formed is somewhat that of the position which a man assumes when sitting on a saddle. Saddle joints, like the condyloid, allow of all kinds of movements, except rotation.

185. Gliding Joints.—This is a form of articulation in which the surfaces of the connecting bones are nearly flat and the amount of motion between them limited by the ligaments or osseous processes surrounding the joint. There is less motion in this form of joint than in any of the other freely movable joints. Examples of this type are the articulation between the individual carpal and tarsal bones and between the articular processes of the vertebræ of the spinal column.

186. The Kinds of Movements Admitted in Joints.—The types of movements admissible

in joints are *gliding*, *angular*, *circumduction*, and *rotation*.

187. GLIDING MOVEMENT.—In this form of motion one surface moves or glides upon another without any angular or rotary movement. It is common to all joints, but it is the only movement of which the gliding joints are capable.

188. ANGULAR MOVEMENTS.—Angular movements are those in which the angle between two bones is increased or diminished. The movements included under this heading are *abduction* and *adduction*, *flexion* and *extension*.

In *adduction*, the part is brought toward the central line of the body; in *abduction*, it is drawn away. In the hands and feet the middle phalanx is considered the middle line, hence the thumb is abducted when it is drawn toward the middle finger, and adducted when it is extended. *Flexion* is the bending or flexing of a part, and *extension* the opposite.

189. CIRCUMDUCTION.—In circumduction, a part is so moved that it describes a cone-shaped figure, the joint being considered the apex of the cone, and its base the circle described by the distal end of the moving limb.

190. ROTATION.—In this form of motion a limb is turned on its own axis. Rotation of the forearm results in the *supination* and *pronation* of the hand, by supination being meant the turning of the palm forwards, and by pronation, the turning of the palm backwards.

191. Sprains and Dislocations.—Too forcible movement of a joint, such as occurs in slipping or falling, is likely to twist it and cause stretching or tearing of some of the ligaments holding the bones in apposition. If this injury to the ligaments is not complicated by displacement of the articulating bones, it is known as a sprain; if a bone is displaced, the injury is called a dislocation.

The Teeth

As dentine, the chief substance of the teeth, is similar to bone, and as the teeth, like the bones, remain as a part of the skeleton after the softer tissues of the dead body have become disintegrated and dissociated, it seems well to consider the teeth in connection with the bones.

192. Location of Teeth.—The teeth are contained in the cavities of the alveolar[1] processes of the upper and lower maxillary bones.

193. The Gums.—The alveolar processes are covered with the gums. These consist of dense fibrous tissue covered with mucous membrane. The gums of each jaw are connected with the periosteum lining the alveolar cavities or tooth sockets. This dental periosteum serves as a means of attachment of the teeth to their sockets, and, being very vascular, as a source of nourishment for them.

194. Parts of a Tooth.—Each tooth consists

[1] From the Latin *alveolus*—little trough.

of three parts: (1) a *crown* or *body* which projects beyond the level of the gums; (2) a *root* or *roots* contained within the alveolar cavity; (3) a *neck*, the constricted portion between the root and the crown, which is normally encircled by the free margin of the gums.

195. NATURE OF TOOTH SUBSTANCE.—The substance of the teeth may be said to consist of three kinds of material: dentine, enamel, and dental pulp.

196. *Dentine*,[1] which constitutes the general framework of the teeth, closely resembles bone in its chemical composition, but it contains a larger per cent. of mineral matter and is much harder. It is, next to enamel, the hardest tissue in the body.

Enamel, which forms a thin covering over the crown of teeth, resembles bone and dentine in its composition, but is harder and more compact.

197. *Dental pulp*. The pulp consists of a loose connective tissue and cells, and a number of blood-vessels and nerves which enter a tooth through a small aperture in the point of its root.

198. STRUCTURE OF TEETH.—On making a vertical section of a tooth, a hollow cavity will be found in the interior. This cavity is situated in the base of the crown and is continuous with a canal that traverses the center of each root and opens by a minute orifice at its extremity. The shape of the cavity resembles the general outline of the teeth. Its wall is composed of dentine, and

[1] From the Latin *dens*—a tooth.

the part constituting the crown is covered with enamel. The cavity is filled with dental pulp and is, therefore, generally called the *pulp cavity.*

199. TEMPORARY AND PERMANENT TEETH.—During the course of his life, man is provided with two sets of teeth, which make their appearance at different times. The teeth comprising the first set are known variously as the *temporary, milk,* and *deciduous teeth.* They are twenty in number, ten in each jaw, and appear gradually, as shown in the table, paragraph 204, between the ages of six months and two and a half years. Usually, at about six years of age they begin to drop out and leave space for their successors. The teeth replacing the temporary set are known as the *permanent teeth.* They number thirty-two, sixteen in each jaw. The order in which they appear can be seen in the table, paragraph 205.

200. NAMES OF TEETH.—Teeth are not all the same shape, and according to their form they are classified as: *incisors, canines, bicuspids,* and *molars.*

201. **The incisors or cutting teeth,** so called from their broad, sharp edge, which especially adapts them for cutting the food, are the front teeth; they are eight in number, four in each jaw.

The canine or eye teeth are larger and stronger than the incisors and have a sharp-pointed edge. In the human animal they serve the same purpose as the incisors. They are four in number, two in each jaw, one on either side of the incisors.

202. **The bicuspid teeth** receive their name from the two dents or cusps in the lower surface of their crown, which is broad and flat. There are eight bicuspid teeth in the permanent set, four in each jaw, two being placed immediately behind each of the canine teeth; but there are none in the temporary set of teeth. The root of the bicuspids generally contains a deep groove which divides it almost in two.

203. **The molars** are the largest of the teeth. They have broad, flat crowns which adapt them for their purpose of grinding and pounding the food. There are eight molars in the temporary set and twelve in the permanent. The root of the molars is divided into from two to five fangs.

204. NUMBER OF EACH VARIETY OF TOOTH IN THE TEMPORARY AND PERMANENT SETS AND THEIR ORDER OF APPEARANCE.—In the temporary set of teeth there are four incisors, two canines, and four molars in each jaw. The figures given in the following table indicate in months the age at which each tooth appears:

Lower Central Incisors	Upper Incisors	1st Molars and Lateral Incisors	Canines	Second Molars
6-9	8-12	12-15	18-24	24-30

In nearly all cases the teeth of the lower jaw are cut shortly before the corresponding ones of the upper jaw.

205. In the permanent set of teeth there are four incisors, two canines, four bicuspids, and twelve molars in each jaw. The figures in the

table represent the year of life in which each tooth is cut.

First Molars	Incisors		Biscuspids		Canines	Second Molars	Third Molars or Wisdom
	Central	Lateral	First	second			
6	7	8	9	10	12-14	12-15	17-25

206. The ages given in these tables for the eruption of the teeth are the average, but there is considerable variation even in healthy children, some cutting their first teeth before six months and others not until nearly twelve months. Diseases such as rickets and marasmus retard the eruption period very considerably. The molars of the permanent teeth do not replace temporary teeth but are added gradually as the jaws develop. The third molars, commonly known as the wisdom teeth because of their late appearance, are sometimes unerupted through life from want of sufficient jaw space.

207. Development of Teeth.—Teeth are developed from the downward growth of epithelial cells of the mucous membrane, the alveolar processes, and the maxillary bones, the enamel being derived from the outer cells and the dentine and pulp from the deeper structures. The development of the temporary teeth commences about the sixth week of intra-uterine life and that of the permanent (except the second and third molars) about the sixteenth week. The second permanent molars are thought to originate about the third month after birth, and the third molars or wisdom teeth about the third year.

CHAPTER VI

MUSCULAR[1] TISSUE

Where Found. Chemical Composition. Different Kinds. Names and Nature of Each Variety. Special Characteristics of Muscular Tissue. Nature of Irritability and Stimuli. Nature of Contraction. Chemical Changes that Take Place in Muscle as the Result of Contraction. Cause and Result of Muscle Fatigue. Tetanus. Nature, Cause, and Purpose of Muscle Tone. Conditions that Cause Variation in Muscle Tone. Difference in the Contraction of Voluntary and Involuntary Muscle. Extensibility and Elasticity of Muscle. Nature of Skeletal Muscles. Method of Attachment, Size, Shape, Number of Skeletal Muscles. Names, Situation, Origin, and Insertion of Some of the More Important Skeletal Muscles.

HAVING finished the study of the osseous tissue and the bony framework of the body, we will take up that of the tissue which forms the bulk of the substance covering the framework; viz. the muscular tissue. This tissue constitutes more than a third of the body weight and in addition to forming the main substance of the fleshy parts of the body, it enters very largely into the structure of the majority of the internal organs.

[1] From the Latin *musculus*—a muscle.

The branch of anatomy concerned with the muscles is known as myology, from the Greek *myos*—a muscle, and *logos*—a discourse.

208. Chemical Composition of Muscular Tissue.—The substances known to be constituents of muscular tissue are: (1) proteins—chiefly substances known as *myogen* and *myosin*[1]; (2) fats; (3) carbohydrates—chiefly glycogen and glucose; (4) inorganic salts; (5) pigments—*i. e.* coloring matter; (6) ferments[2]; (7) waste substances—*i. e.* simple substances resulting from the breaking down of the more complex compounds.

209. Different Kinds of Muscular Tissue.—There are three varieties of muscular tissue, viz.:

(1) *Plain muscular tissue*, known also as *unstriped*, *non-striated*, *visceral*, and *involuntary*.

(2) *Striped muscular tissue*, called also *striated*, *skeletal*, and *voluntary*.

(3) *Striped* or *striated*, *involuntary cardiac tissue*.

Plain Muscular Tissue

210. Meaning of Names.—This form of muscular tissue received the names of *plain*, *unstriped*, and *non-striated*, because its fibrils are not striped or striated, as are those of the second type. It was called *visceral*, because it constitutes a large portion of the substance of many of the viscera—*i. e.*, internal organs—and *involuntary*, because its nerve supply is not connected with those parts of the nervous system that have to do

[1] See Glossary.

[2] Described in connection with metabolism and heat production, Chapters XXVIII and XXIX.

with will and its action is therefore involuntary and cannot be controlled by voluntary effort.

211. STRUCTURE.—Plain muscle is made up of elongated cells, varying from $\frac{1}{600}$ to $\frac{1}{300}$ of an inch in length, and consisting of a delicate elastic outer membrane or sheath filled with *muscle plasma* and a nucleus. These cells are placed side by side and end to end, and cemented together in variously shaped bundles. These bundles are both separated and held together and to other tissues and membranes by connective tissue.

212. NATURE OF PLASMA OF MUSCLE CELL.—When, after the death of an animal, the plasma of muscle is examined under a microscope it appears to consist of minute fibrils and a granular, structureless substance known as *sarcoplasm*. The plasma of the cell is known as the *contractile substance*, because the power of contraction which characterizes muscular tissue is due to the contractility of the plasma fibrils.

Striated Muscular Tissue

213. MEANING OF NAMES.—This form of muscular tissue is, as previously stated, known also as *striped*, *skeletal*, and *voluntary* muscular tissue. It is called *striped* and *striated* because the fibrils of its protoplasm consist of alternate light and dark parallel transverse stripes which give the muscles a striped or striated appearance. It is called *skeletal* because it forms the muscles which

cover and are attached to the skeleton, and *voluntary*, because its movements are under the control of the central nervous system and, to a great extent, of the will.

FIG. 52.—Fragment of a fiber of cross-striped muscular tissue showing fibrils separated at one end by teasing. (Gerrish.)

214. STRUCTURE.—Striped muscle is composed of slender tube-like fibers about an inch or more in length and $\frac{1}{600}$ of an inch in diameter. The walls of the fibers are composed of an exceedingly thin, transparent, elastic membrane called the *sarcolemma*.[1] The fibers are filled, as in the cells of plain muscle tissue with muscle plasma, which is apparently similar to that in the cells except for the shading of the fibrils, which is responsible for the striped appearance of skeletal tissue, and the presence of several nuclei instead of one in each fiber. These muscle fibers, together with numerous blood-vessels and nerves are held in bundles with an exceedingly delicate connective tissue.

FIG. 53.—Fragment of a fiber of cross-striped muscular tissue, hardened, showing transverse cleavage. (Gerrish.)

FIG. 54.—Transverse section of muscle-fiber, showing nuclei. (Gerrish.)

[1] From the Greek *sarkos*—fleshy, and *lemma*—a husk.

The bundles, in turn, are bound with similar, but stronger, tissue to form muscles of varying length, breadth, thickness, and shape.

FIG. 55.—Part of a fiber of cross-striped muscular tissue, showing the alternating bands. (Gerrish.)

Cardiac[1] Tissue

215. MEANING OF NAME.—Cardiac tissue is so called because it is found only in the heart substance. It is striped like the skeletal muscle, but there are several points of difference between the two, the more marked of which are: (1) Its action is involuntary; (2) its fibers are shorter; (3) the bundles into which the fibers are bound are nearly square, and (4) are held together with branches or offsets of the fibers; (5) no sarcolemma has been proved to exist.

FIG. 56.—Cell of cardiac muscular tissue. (Gerrish).

[1] From the Greek *kardia*—the heart.

These differences in structure are thought to be of great importance in the action of the heart muscle, which is different from that of other muscular tissue. The characteristics of cardiac muscle will be considered in the chapter concerned with the circulation.

216. Blood and Nerve Supply.—All types of muscular tissue are plentifully supplied with blood, which they receive from capillaries arranged in networks around the fibers or cells, outside the sarcolemma or membranous wall. The capillaries do not enter the membrane, and interchange of substance between the blood and the cell contents takes place by osmosis.[1] Muscular tissue is provided also with innumerable nerves. The skeletal muscles get their supply from the cerebro-spinal, or, as it is also called, the central nervous system, but the cardiac and involuntary muscle tissue are supplied with fibers from both the sympathetic and central systems.

217. Special Characteristics of Muscular Tissue.—These are irritability,[2] contractibility,[3] extensibility, and elasticity.

218. Irritability and Stimuli.—By irritability of tissue is meant its power of responding to stimulation, and the manner in which a tissue

[1] The diffusion—passage—of fluid through membrane.

[2] Irritability is peculiar to nervous and muscular tissue and certain epithelial cells, as those of glandular organs.

[3] Contractibility is peculiar to muscular tissue, white blood corpuscles, and ciliated epithelium.

responds to stimulation is by performing its special function; thus, a gland when stimulated will secrete, and a muscle will contract. In the living muscle the most common source of stimulation is the nervous system[1]; the nerve impulse[2] being sent from the brain, spinal cord, or sympathetic ganglia[3] along the motor nerves to the muscles where it causes, in some unknown way, certain chemical changes to take place[4] in the cell, which result in contraction of the tissue.

219. Muscular Contraction.—By contraction is meant shortening. As previously stated in paragraphs 217 and 218, the cells and fibers of muscles are long and slender, but when the tissue is stimulated they become shorter and broader, which results in the muscle becoming contracted or shortened so that its two ends, and whatever is attached to these ends, are brought nearer together; *e. g.*, the contraction of certain muscles of the arm will flex the forearm, and contraction of certain muscles of the forearm will flex the wrist, etc. Thus it can be seen that muscular contraction is the active agent in the causation of all the movements of the body, and, as stated in the preceding paragraph, muscular contraction in the living body is usually the result of nerve stimulation.

[1] Though in the living animal nerve impulse is the usual source of stimulation, muscular tissue can be stimulated by electricity and by chemical and physical agents.

[2] See paragraph 321.

[3] See paragraph 307.

[4] See paragraph 220.

220. Results of Muscular Contraction.—Muscular contraction is associated with complicated changes in the muscle tissue the nature of which is very imperfectly understood. It is known, however, that they include processes of splitting and oxidation whereby large molecules are reduced to smaller ones, such as lactic and other acids, carbon dioxid and water, with the liberation of heat[1] and of the energy which held the atoms of the complex substances together. In warm-blooded animals some of the heat is utilized for the purpose of maintaining body temperature, and energy[2] is required to further muscular contraction.

221. Muscle Fatigue.—A small amount of the substances formed in muscle in connection with its contraction assists in the process, especially in the beginning of activity, but, if a muscle is caused to work at a greater rate than the lactic acid produced is broken down by the oxidation process, it becomes fatigued *i. e.*, incapable of full activity or even of any at all. The cause of this is not only the presence of the waste products (called *fatigue poisons*), but also deficiency of material necessary to provide the energy required for contraction, this being broken down more rapidly than it is replaced. The conditions causing the sense of fatigue affect some part or parts of the nervous system, as well as the muscle. This will be further discussed in paragraphs 309, 312, 348.

[1] Heat. See paragraph 801.
[2] Energy. See Glossary.

222. Recovery from Fatigue.[1]—The sense of fatigue disappears after the fatigue poisons have been eliminated from the system, in the respiration, urine, etc., and fresh nutrient material has been brought to the tissues by the blood; the blood getting the supply from the food that has been digested and absorbed. Rest is, of course, necessary for recovery, because as long as the body is in motion more waste products are being formed. Massage gives relief in severe fatigue because it hastens the passage of the poisons into the blood stream, improves the circulation of the blood and lymph, and thus accelerates the elimination of the poisons.

223. Tetanus.—Very few muscular movements are the result of a single contraction arising from a single stimulus, but are rather the result of a fusion of a series of rapidly following stimuli, which keep the muscle in a condition of contraction so long as the stimuli are sent in or until the muscle loses its irritability from fatigue. A contraction of this sort is termed *tetanus of muscle*. This is not to be confused with the disease of the same name.

224. Nature and Cause of Muscle Tone or Tonus.—In the living body the muscles are normally in a state of continuous contraction, slight in extent but varying in degree from time

[1] Sleep is thought to be due, at least in part, to the effect of these fatigue poisons on the system; see Chapter XXVI.

to time. This state of slight, constant contraction is known as *muscle tone* or *tonus*. It is due to the fact that the nerves are constantly sending light nerve impulses into the muscles and thereby causing slight chemical changes in the tissues, with the result that the muscles remain in a state of slight contraction.

225. Causes of Nerve Impulse.—In order to discharge impulses, the nerves must first be stimulated, and this they are continuously: during waking hours through impressions received by the sensory nerves [1] connected with the senses of sight and hearing, through those of the skin which are affected by variations in temperature, contact of clothing, etc.; and at all times through the sensory nerves from the muscles.

226. Value of Muscle Tone.—Muscle tone is thought to be of importance to the body in several ways, viz., it, together with the extension of muscle—see paragraph 232—permits of a quicker response of muscle tissue to stimulation; (2) it assists in maintaining the circulation of the blood and lymph; (3) in controlling the regulation of body heat and nutrition. These two last uses of muscle tone will be referred to again in the chapters dealing with the circulation of the blood and metabolism.

227. Conditions that Cause Variation in Muscle Tone.—As stated in paragraph 224, the

[1] The nerves which carry impressions from the periphery to the brain.

degree of tonus in muscle is somewhat variable. The most common causes of increased tonus in the living organism are: (1) muscular activity; (2) mental activity; (3) lowering of the surrounding temperature.

228. Exercise as a Cause of Muscular Tone.—Exercise means muscular contraction, and is therefore, of course, attended with the production of the products of disintegrated tissue substance. The bad result of over-exercise has been already discussed, but a normal amount of exercise is not attended with a greater production of waste substances than the system can easily get rid of, and when present in moderation these improve muscular tone, and consequently the circulation of the blood and lymph, nutrition, etc.

229. Mental Activity as a Cause of Increased Muscular Contraction.—An example of increased muscular contraction as the result of mental activity is the tension that often accompanies excitement of any kind, or intense mental concentration—as when listening to eloquent oratory, a very exciting tale, etc. This accounts for the feeling of relaxation that follows such concentration, the fatigue that follows protracted excitement or concentration, and the unusual strength that results from extreme excitement.

230. Lowering of Temperature as a Cause of Increased Muscular Tone.—When the skin becomes chilled certain of the sensory nerves

therein become stimulated and act upon the nerve centers[1] in the brain or spinal cord, in consequence of which there will be an increase in the impulses sent along the motor nerves to the muscles, which will cause an increase in the degree of muscle contraction. If the chilling is severe the increase in muscle contraction may be so intense that shivering will result. As stated in paragraph 220, muscular contraction produces heat and the increased tonus following chilling is one of nature's methods of heat regulation.

231. Differences in the Contraction of Involuntary and Voluntary Muscle.—Contraction of the involuntary muscle of the viscera takes place more slowly and regularly and lasts longer than that of voluntary muscle. If, for any reason, such as excessive nervous irritation, contraction takes place more quickly than usual in involuntary muscle, pain will result. A familiar example of this is the gastric or intestinal cramp that often follows the taking of indigestible food or of drastic cathartic medicines, etc.

232. Extensibility and Elasticity of Muscle.—It was said in paragraph 217 that muscle is extensible—*i. e.*, it can be stretched—and elastic—*i. e.*, it can return to its original shape after it has been stretched. In our bodies the skeletal muscles are, normally, always in a condition of slight tension, being stretched from bone to bone. This condition is of great importance

[1] See paragraph 329.

in the functioning of the muscles, because (1) a stretched muscle will contract more quickly than one which is relaxed; (2) smoothness of movement is in many parts of the body dependent upon it. To understand how the latter fact can be true it is necessary to know that the majority of the skeletal muscles are so arranged that certain muscles or groups of muscles oppose or are antagonistic to the action of others. For instance, on the anterior surface of the forearm are muscles called flexors, because their contraction flexes the wrist, hand, or fingers; and on the posterior surface are muscles, called extensors, that cause extension. Now, as these extensor muscles are in a state of tension, the flexors when stimulated must overcome the resistance of the extensors, and therefore contraction takes place more slowly and evenly; this prevents jerking, such as takes place when a muscle is very strongly stimulated, as by an electric shock.

The Skeletal Muscles

233. Nature of a Muscle.—"A muscle is an organ whose essential part is a mass of striated muscular tissue, prolonged at its opposite ends or margins by cords, bands, or sheets of white fibrous tissue which are fastened to other structures, usually bones. The muscular tissue is contractile, and is the active portion of the organ; the fibrous

is strong and flexible, but is only passive. The contractile portion is called the muscle proper, the belly or the body of the muscle; the fibrous extensions are called tendons, and sometimes when greatly expanded, aponeuroses. The muscle proper may be compared to an engine in which force is generated; its tendons to the ropes by which the power is applied to distant objects."[1]

234. Origin and Insertion of Muscles.—A muscle is attached to two objects. The part fastened to the more fixed of these objects is spoken of as the *origin of the muscle*, and the part attached to the body which the muscle moves the most easily is called the *insertion of the muscle.*

235. Methods of Attachment.—Muscles have several different kinds of attachment. (1) They are usually connected with bones by means of tendons and ligaments, the contractile muscle fibers gradually blending with the non-contractile, tough tendon, or ligament fibers, which in turn become gradually blended into the substance of the periosteum to which they hold the muscle, and thus when the muscle contracts, the tendons and ligaments, being unable to do so, pull on the two bones, bringing them nearer together. (2) In several parts of the body one muscle is attached to another by means of a broad, flat band of fibrous tissue, termed an *aponeurosis.* (3) Groups of muscles are held

[1] *Text-Book of Anatomy by American Authors*, page 259. Gerrish. Lea Bros. Co.

together and muscles are connected with the skin and with other tissues by thin sheets and bands of fibrous tissue known as fasciæ.

236. Size and Shape.—Muscles vary in size from the fraction of an inch to nearly two feet in length. Their shape, also, is very diverse, some muscles being thick, others thin and sheet-like some broad, others slender, etc.

237. Nomenclature and Number.—The voluntary muscles are nearly always called by their Latin names, which are usually descriptive either of their action, their situation, their shape, or some special characteristic in their structure. Their number is generally estimated as 405. With a few exceptions they occur in pairs. As a knowledge of the names of the muscles is not of much importance to nurses, only the larger muscles and those likely to be referred to in describing different parts or functions of the body will be mentioned here. The ones which are so constantly referred to that it is well to remember their names and situations are starred. In reading the following description of the muscles it is to be remembered that though, as a rule, only one muscle or group of muscles is mentioned, those spoken of here occur in pairs, with the exception of the occipito-frontalis and the diaphragm.

Muscles of the Head and Face

238. *The names of the principal muscles of the head and face are:*

Occipito-frontalis	*Pterygoid externus*	
Recti, 4 for each eye	*Pterygoid internus*	
Oblique, 2 for each eye	*Buccinator*	
Levator palpebræ superioris	*Orbicularis oris*	
Masseter	*Geniohyoglossus*	*of the tongue*
Temporalis	*Styloglossus*	*of the tongue*
	Lingualis	*of the tongue*

*239. Occipito-Frontalis.—*This consists practically of two muscles: the occipital, which covers the back or occiput of the head, and the frontal, which covers the front of the skull and is inserted in the skin and muscles of the root of the nose and eyebrows. The two muscles are held together by an aponeurosis, which covers the top of the head. The frontalis is the more active muscle. Action: it elevates the brows, causing transverse wrinkling of the forehead.*

*240. Muscles of Eyeball.—These are the superior, inferior, internal, and external recti, and the superior and inferior oblique. The four recti[1] muscles have their origin in the long structure of the orbital cavity. At the apex of the eye they pass forward and are inserted in the sclerotic[2] coat of the eye, near the margin of the cornea[3]; the superior at the upper part of the eye; the inferior opposite it at the lower margin; the external on the outer side; and the internal on the inner side.

*241. Action.—Contraction of the superior rectus rolls the eyeball upward; contraction of

[1] *Recti*, singular *rectus*, Latin—straight.
[2] Described in paragraph 948.
[3] *Ibid.*, 949.

the inferior, rolls it downward. The right external rectus of one eye and the left internal of the other

FIG. 57.—Superficial muscles of head and neck. (Gerrish.)

act together, when a person is looking toward the right, to turn the eyes to the right; and the left external rectus and right internal act together to turn the eyes toward the left. Both internal recti

act together to turn both eyes toward the middle line, as is done when directing the vision toward a near object in front of the eyes. The superior oblique has its origin in the inner side of the orbital cavity, and is inserted in the outer surface of the eyeball, in the sclerotic coat, between the superior and the external recti. The inferior oblique arises from a depression in the orbital articulation of the superior maxillary, near the nasal duct. It passes around to the outer side of the eye and is inserted near the tendon of insertion of the superior oblique. Action: the oblique muscles rotate the eyeball on its antero-posterior axis. This kind of movement is particularly required for the correct viewing of an object when the head is moved laterally, as from shoulder to shoulder.

FIG. 58.—Muscles of eyeball. (Gerrish.)

242. LEVATOR PALPEBRÆ SUPERIORIS.—*The name of this muscle—lifter of the upper lid—denotes its action. It arises from the bony structure at the back of the eye and is inserted in the upper lid.*

243. MASSETER.[1]—*Origin: superior maxilla and zygomatic arch. Insertion: angle of lower jaw. Action: assists in mastication.*

[1] From the Greek *massaomai*—to chew.

*244. TEMPORAL.—*Origin: fossa and fasciæ of the temporal bone. Insertion: coronoid process of the lower jaw bone. Action: assists in mastication.*

245. INTERNAL PTERYGOID.[1]—*Origin, insertion, and action similar to the temporal.*

246. EXTERNAL PTERYGOID.[1]—*Origin: sphenoid, ethmoid, palate, and superior maxillary bones. Insertion: lower jaw. Action: assists in mastication.*

247. BUCCINATOR.[2]—*Origin: alveolar processes of the upper and lower jaw bones. Insertion: muscles of the lips. Action: compresses the cheeks, so that food is kept in immediate contact with the teeth, and assists in such motion as blowing a trumpet, etc., hence its name.*

248. ORBICULARIS ORIS.[3]—*This is a sphincter*[4] *muscle, elliptic in form, which surrounds the mouth and extends from the nostrils to the chin. Action: it closes the lips.*

Chief Muscles of the Tongue

249. GENIOHYOGLOSSUS.[5]—*Origin: superior tubercle of lower jaw. Insertion: body of the hyoid bone and under surface of the tongue from base to*

[1] From the Greek *pteron*—a wing, and *eidos*—form. These muscles were so named from their shape.

[2] Buccinator. From the Latin *bucinare*—blow a trumpet.

[3] Orbicularis Oris. Latin, pertaining to an orb, and *oris*—the mouth.

[4] Sphincter. From the Greek *sphiggo*—to close.

[5] Genio-hyo-glossus. From the Greek *geneion*—the jaw, *huoeides*—the hyoid, and *glossa*—the tongue.

point. Action: it protrudes as well as retracts the tongue, and also depresses it, as in the act of sucking.

250. STYLOGLOSSUS.—*Origin: the styloid processes of the temporal bone. Insertion: side and under surface of the tongue. Action: draws the tongue backward.*

251. LINGUALIS.—*This muscle forms the bulk of the tongue. The fibers of the lingualis blend with the other muscles of the tongue and some of them are inserted in the hyoid bone. Action: it draws the center and apex of the tongue downward.*[1]

Muscles of the Neck

The principal muscles of the neck are:

Platysma[2] *Myoides*[3]
Sternocleidomastoid
Sternothyroid

252. PLATYSMA MYOIDES.—*A thin, broad muscle covering the upper part of the shoulder and side of the neck. Origin: the deep fasciæ over the pectoral, deltoid, and trapezius muscles. Insertion: the lower jaw. Action: depresses the jaw and angle of the mouth, and wrinkles the skin of the neck.*

[1] Anæsthetics, as ether and chloroform, when given to an individual in sufficient quantity to produce general anæsthesia, depress the nervous system and, consequently, lessen muscular tonus. This loss of tone, or relaxation of the muscle in the tongue, makes that organ likely to fall back over the trachea—air passage to the lungs—unless the head is kept turned on one side and the jaw pressed forward and upward.

[2] Platysma. From the Greek *platus*—broad.

[3] Myoides. From the Greek *myo*—muscle, and *oides*—likeness.

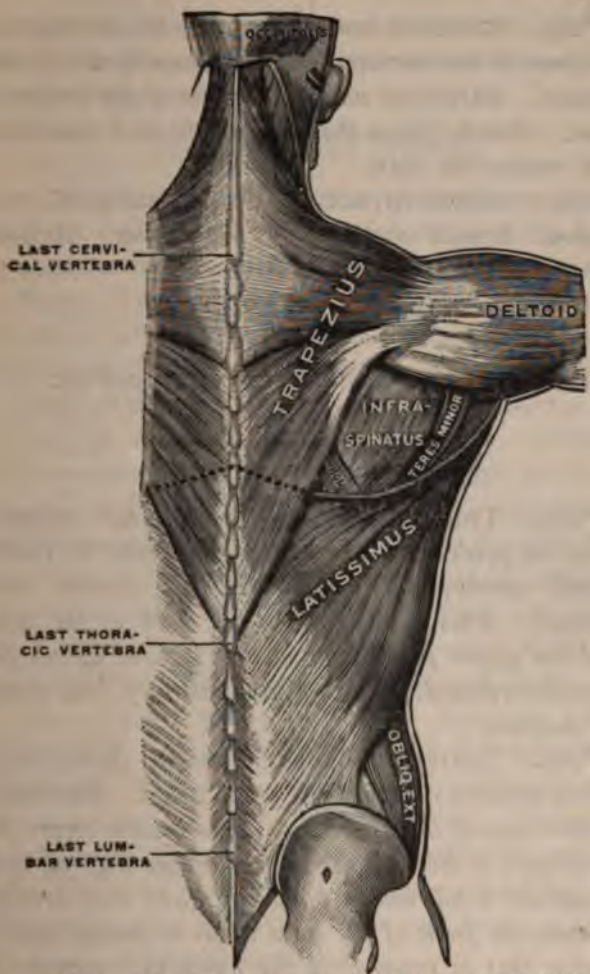

FIG. 59.—Muscles in the superficial layer of the back. (Gerrish.)

*253. STERNOCLEIDOMASTOID.[1]—*Origin: the upper part of the sternum and the inner border of the clavicle. Insertion: mastoid process of the temporal bone. Action: flexes the head on the neck and chest and rotates the chin.*

254. STERNOTHYROID.[1]—*Origin: sternum. Insertion: thyroid cartilage of the larynx. Action: depresses the larynx.*

Muscles of the Back

The largest superficial muscles of the back are:

The trapezius
The latissimus dorsi

*255. THE TRAPEZIUS.—*Origin: the occipital bone, the processes of the seven cervical and the twelve dorsal vertebræ. Insertion: in the clavicle and scapula. This muscle covers the back of the neck and the upper part of the back. Action: draws the shoulder upward, backward, and laterally, and moves the scapula.*

*256. LATISSIMUS DORSI.—*Origin: the six lower dorsal vertebræ and the crest of the ilium. Insertion: in the front of the humerus. This muscle covers the lower part of the back and converges (see Fig. 59) into a narrow band which passes upward and around towards the front of the chest where it merges into a tendon that is inserted in the humerus. Action: it draws the humerus downward and backward, while*

[1] These muscles are named from the bones and cartilages of their origin and insertion, *cleido* meaning clavicle.

rotating it inward; it helps raise the lower ribs in forcible inspiration, and it helps in the movements of climbing and pulling.

Muscles of the Thorax

257. *The principal muscles of the thorax are the internal and external intercostal muscles, the levatores costarum, the triangularis sterni.*

*258. The External and Internal Intercostal Muscles.—*These two sets of muscles, as their names imply, are situated between the ribs, the internal behind the external. Each external muscle arises from the lower border of a rib, runs downward and forward and is inserted in the upper border of the rib next below. Action of external intercostals: they raise the ribs. Each of the internal intercostals arises from the inner surface of a rib and its cartilage, just above their lower border, runs down and backward, and is inserted in the inner surface of the rib next beneath. Their action is not agreed upon.*

259. Levatores Costarum.—*They are twelve in number. Each one arises from the tip of the transverse process of a vertebra and is inserted into the outer surface of the rib next below. Action: it was thought formerly that these muscles elevated the ribs, hence their name; but it is now considered that they only assist in the extension and lateral flexion of the dorsal part of the thorax.*

260. The Triangularis Sterni.[1]—*Origin: the*

[1] Triangular muscle of the sternum, so called from the shape and attachment of the sternum.

lower part of the sternum and the cartilages of the lower two or three true ribs. Insertion: the outer extremities of the costal cartilages, from the second to the sixth. Action: depression of those ribs to the cartilages of which it is attached.

*261. THE DIAPHRAGM.—The diaphragm is a

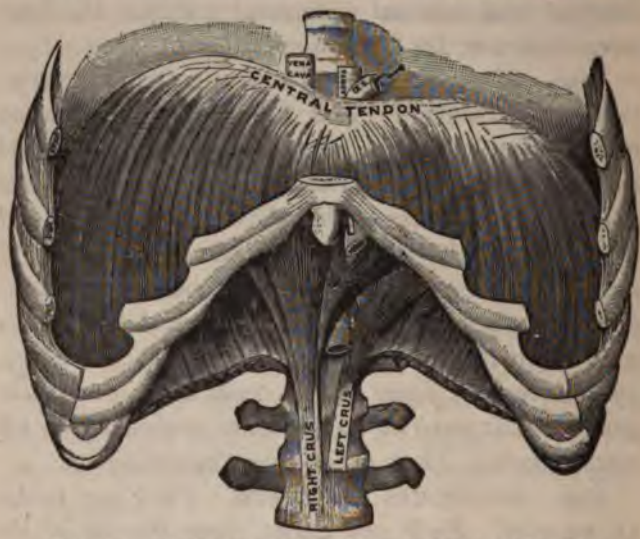

FIG. 60.—Diaphragm, viewed from in front. (Gerrish.)

thin musculo-fibrous septum placed obliquely between the thoracic and the abdominal cavities, forming the floor of the former cavity and the roof of the latter. It consists of a tendon which forms its central portion, and a muscle which surrounds and is inserted in the tendon. The muscle has its origin in the lower boundaries of the thoracic framework—the sternum, some costal cartilages,

several vertebræ, and fibrous bands connected with the last rib. The shape of the diaphragm is that of a flattened dome, its highest point being the central tendon. While passive, its lower part is in apposition with the chest walls. On contraction of the muscular portion, the tendon, being non-contractile, is pulled upon and drawn down so that the dome is flattened and the capacity of the thoracic cavity thus greatly increased. There are three large foramina in the diaphragm for the passage of the esophagus,[1] the aorta,[2] and the inferior vena cava,[3] also several smaller ones for the entrance and exit of blood-vessels, lymphatics, and nerves to and from the lower half of the body. Action: the diaphragm is the principal muscle of respiration and at times it assists the abdominal muscles in their function.

262. Abdominal Muscles.—*The chief muscles of the abdomen are:*

External oblique
Internal oblique
Transversalis abdominis
Rectus abdominis

263. Abdominal Aponeuroses, Linea Alba,[4] and Poupart's Ligament.—*The oblique and transversalis muscles of the two sides of the abdomen are*

[1] Esophagus. The tubes connecting the mouth with the stomach.
[2] Aorta. The main artery.
[3] Vena Cava. One of the largest veins of the body.
[4] Linea Alba. Latin, white line.

united by means of their aponeuroses, which interlace in the median line of the abdomen, forming a heavy white cord which extends from the ensiform cartilage to the symphysis pubis and is known as the linea alba. The aponeuroses cover a considerable portion of the front of the abdomen, and at their lower extremity extend in a heavy band from the spine of the pubis to the anterior superior spine of the ilium. This ligament was named Poupart's ligament, after the surgeon who first described it; also, it is called, from its location, the inguinal ligament.

264. EXTERNAL OBLIQUE MUSCLE.—*Situation: in the superficial surface of the side and front wall of the abdomen. Origin: the outer surface of the lower eight ribs. Principal points of insertion: the anterior half of the iliac crest, the linea alba, Poupart's ligament.*

265. INTERNAL OBLIQUE.—*Situation: behind the external oblique. Origin: outer half of Poupart's ligament, the center of the crest of the ilium and the lumbar fasciæ. Insertion: the lower borders of the six lower costal cartilages, the ensiform process, the linea alba, and the pubic bone.*

266. TRANSVERSALIS.[1]—*Situation: beneath the internal oblique. Origin: the inner surface of the lower six costal cartilages, the transverse processes of the lumbar vertebræ, the crest of the ilium, and the outer third of the inguinal ligament. Insertion: the linea alba and the crest of the pubic bone.*

[1] So called because the greater part of the fibers have a transverse—horizontal—direction.

267. Rectus[1] Abdominis.—*Nature and situation; a long slender, flat muscle which extends along the whole length of the front of the abdomen. The aponeuroses of the oblique and transversalis muscles, which are all blended into one, separate at the outer border of the rectus, forming two sheets, which pass one under and the other over the muscle, and unite again at the medial border, forming, with the aponeuroses of the opposite side, the linea alba. Origin of the rectus: the pubic bone. Insertion: the fifth, sixth, and seventh costal cartilages.*

*268. Action of the Abdominal Muscles.—These muscles, by constricting the cavity of the abdomen, compress the abdominal viscera in which action they are materially assisted by the descent of the diaphragm. This action helps in the expulsion of feces from the rectum, urine from the bladder, the contents of the stomach in vomiting, and, in parturition, the fetus from the uterus. The abdominal muscles also assist in respiration[2] and in various movements, such as climbing, flexing the thorax upon the pelvis, rotation of the trunk, etc.

*269. The Inguinal Canal.—In the groin or inguinal region, between the abdominal muscles, is a small crevice called the inguinal canal, through which, in the female, the round ligament of the uterus passes and, in the male, the spermatic cord.

[1] Rectus. So called because its fibers run directly perpendicularly. From the Latin *rectus*—straight.

[2] See Chapter XV. Respiration.

This canal is about an inch and a half long and extends obliquely downward and toward the median line, from an aperture in the fasciæ of the transversalis muscle, called the *internal abdominal ring*. This ring is on a line midway between the anterior superior iliac spine and the symphysis pubis, and about an inch above Poupart's ligament. The canal ends at the external abdominal ring which is in the aponeurosis of the external oblique muscle. As these rings are the frequent seat of hernia they have a special interest for nurses.

270. HERNIA.—By a hernia is meant the protrusion of viscera through an abnormal opening, as of a portion of intestine through one of the weak points of the abdominal wall, such as the umbilicus, the rings described above, and another ring situated below Poupart's ligament, called the *femoral ring*. Hernia in the umbilicus is called *umbilical hernia;* in the inguinal rings, *inguinal hernia*; and in the femoral ring, *femoral hernia*.

271. CHIEF MUSCLES OF THE UPPER EXTREMITY.—*These are named:*

Shoulder	*Pectoralis major* *Pectoralis minor* *Deltoid*
Arm	*Brachialis* *Biceps flexor cubiti* *Triceps extensor cubiti*

Forearm	*Pronators*
	Supinators
	Flexors
Hand	*Extensors*
	Abductors
	Adductors

*272. Movements Caused by the Contraction of the Majority of Muscles of the Upper and Lower Extremities and Arrangement of Muscles.—The movements of which the extremities of the body are capable are: *flexion* and *extension*, *abduction* and *adduction*, *supination* and *pronation*, *circumduction* and *rotation*. The nature of these movements was described in the preceding chapter. As has been already stated, muscles and groups of muscles causing antagonistic movements, as flexion and extension, etc., are so arranged that the antagonistic ones oppose the action of each other, as, owing to the normal extension of the muscles, this secures evenness of movement.

Muscles of the Shoulder

*273. Pectoralis[1] Major.—*Situation: front and upper part of the chest. Origin: the clavicle, sternum, and sixth costal cartilage. Insertion: in the humerus. Action: draws the arm downward and forward.*

[1] Latin *pectoralis*—pertaining to the breast. On account of their location, the pectoral muscles are often classed with the muscles of the thorax, but as their action is concerned with the arm they are as frequently classed with those of the upper extremities or shoulder girdle.

*274. Pectoralis Minor.—*Situation: the chest*

Fig. 61.—Front of chest and shoulder of right side, superficial muscles. (Gerrish.)

(see Fig. 61). Origin: third, fourth, and fifth ribs. Insertion: in the coracoid process of the scapula.

Action: depresses the shoulder and assists in the elevation of the ribs during inspiration.

275. DELTOID.[1]—*Situation: covering the most prominent part of the shoulder and the middle of the outside of the arm. Origin: outer third of the clavicle, outer border of the acromion process, lower border of the spine of the scapula. Insertion: on the outer side of the humerus. Action: it abducts—raises—the arm to a right angle with the trunk, draws the arm forward, if the portion attached to the clavicle works alone, or backward, if only the portion attached to the scapula contracts.*[2]

Muscles of the Arm

276. BRACHIALIS.[3]—*Situation: on the front of the arm. Origin: the humerus. Insertion: the ulna. Action: flexion of the forearm.*

*277. BICEPS.[4]—*Situation: in the front of the arm. Origin: the biceps, as its name implies, has two heads; they both have their origin in the scapula but in different parts. Insertion: in the radius. Action: flexes the forearm.*

278. TRICEPS.[5]—*Situation: in the back of the*

[1] Delta-like muscle. Delta being the name of the Greek letter, the form of which the deltoid is thought to resemble.

[2] The latissimus dorsi, described with the muscles of the back, and some small muscles around the shoulder, oppose the action of the deltoid and adduct the arm—draw it down toward the trunk.

[3] From the Latin *brachium*—the arm.

[4] From the Latin, *bis*—twice, and *caput*—a head.

[5] From the Latin, *tris*—three, and *caput*—a head.

FIG. 62.—Superficial muscles of front of right forearm. (Gerrish.)

arm. Origin: the triceps has three heads, two of which have their origin in the scapula and one in the humerus. Insertion: back of the olecranon process of the ulna. Action: extension of the forearm.

Muscles of the Forearm and Hand

*279. PRONATORS. —*There are two. Situation: the front of the forearm. Origin: (No. 1), both humerus and ulna; (No. 2), ulna only. Insertion: both in the radius. Action: they pronate the radius and, consequently, the hand.*[1]

*280. SUPINATOR. —*Situation: outer part of the forearm. Origin:*

[1] It will be remembered that pronation and supination of the radius are obtained by the rotation of the radius on the ulna.

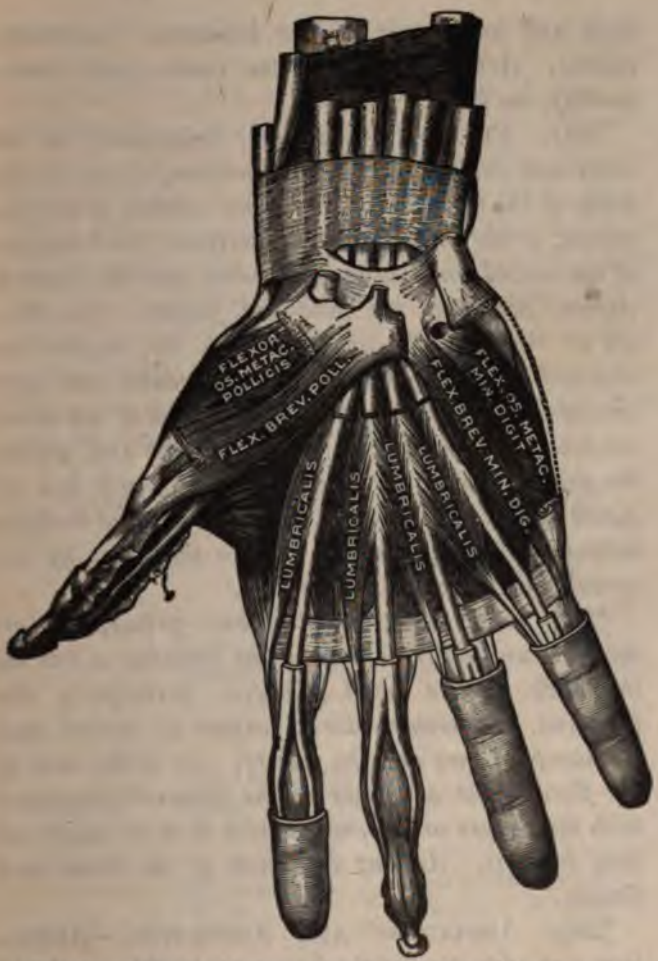

FIG. 63.—Muscles of the right palm. The abductors of the thumb and little finger have been removed. (Gerrish.)

back and lower part of the humerus. Insertion: radius. Action: supinates the radius and, consequently, the hand.[1]

*281. FLEXORS.—*Situation: principally in the front and inner border of the forearm; a few in the palm of the hand. Origin: front surface of the humerus; a few in the ulna. Insertion: front surface of the carpal and metacarpal bones and the fingers. Action: flexion of the hand and fingers. The flexors of the forearm concerned with the fingers are attached to them by means of long tendons, and deep wounds around the wrist or in the palm of the hand are likely to sever some of these tendons, and, unless the severed parts are sewed together, cause loss of power to flex the fingers to which the injured tendons belong. The tendons are held to the wrist by the annular ligaments. See Fig. 63.*

*282. EXTENSORS.—*Situation: principally on the back and outer surface of the forearm; a few on the back of the hand. Origin: principally the humerus. Insertion: dorsal aspect of carpal and metacarpal bones and the fingers. As in the case of the flexors, the extensors of the forearm concerned with the fingers are connected with them by means of long tendons. Action: extension of the hand and fingers.

*283. ABDUCTORS AND ADDUCTORS.—*Abduction and adduction of the forearm takes place only in connection with the arm and by the action of the same

[1] It will be remembered that pronation and supination of the radius are obtained by the rotation of the radius on the ulna.

muscle causing those movements in the arm, but the thumb and each of the fingers have two muscles attached to the base of its first phalanx, one on the radial and one on the ulnar side, by means of which they are abducted and adducted; the abductor being situated, except in the case of the middle finger, on the side farthest from the median line, and the adductor on the side nearest to it. In the middle finger both muscles are abductors, but when the finger is displaced laterally by one of these muscles, it is restored to the middle line by the contraction of the other. These muscles arise from the carpal bones and extend over the palm of the hand.

Chief Muscles of the Lower Extremities.

284. NAMES:

Femoral Region (Thigh)	*Gluteal Region (Buttocks)*	*Gluteus maximus*	*(largest)*
		Gluteus medius	*(middle)*
		Gluteus minimus	*(smallest)*
	Loin	*Psoas magnus*	
	Anterior Region	*Sartorius*	
		Quadriceps	
	Internal Region	*Adductor gracilis*	*(slender)*
		" *magnus*	*(great)*
		" *longus*	*(long)*
		" *brevis*	*(short)*
	Posterior Region	*Biceps*	
		Semitendinosus	*(half tendon)*
		Semimembranosus	*(half membrane)*

Leg	*Anterior Region*	*Tibialis anticus or anterior*	
		Extensors	
	Posterior Region	*Popliteus*	
		Gastrocnemius	
		Soleus	
		Flexors	
		Tibialis posticus or posterior	
	Fibular Region	*Peroneus*[1] *longus (long)*	
		Peroneus brevis (short)	
Foot	*Dorsal Region*	*Extensors*	
	Plantar Region	*Flexors*	
		Abductors	
		Adductors	

Muscles of the Buttocks and Loin

*285. GLUTEI[2] MUSCLES.—*These muscles form the principal part of the substance of the nates or buttocks. The gluteus maximus is the most superficial and the largest. Origin: ilium, sacrum, coccyx. Insertion: great trochanter. Action: extends, abducts, and rotates the thigh outward, and has greater power than any other muscle to maintain the body in the erect position. The gluteus medius and gluteus minimus arise from the outer surface of the ilium and are inserted in the great trochanter. Action: help support the trunk, flex and rotate the trunk inward, and the gluteus minimus also abducts the thigh.*

[1] Peroneus. From the Greek *perone*—fibula.
[2] Glutei. From the Greek *gloutoi*—the buttocks.

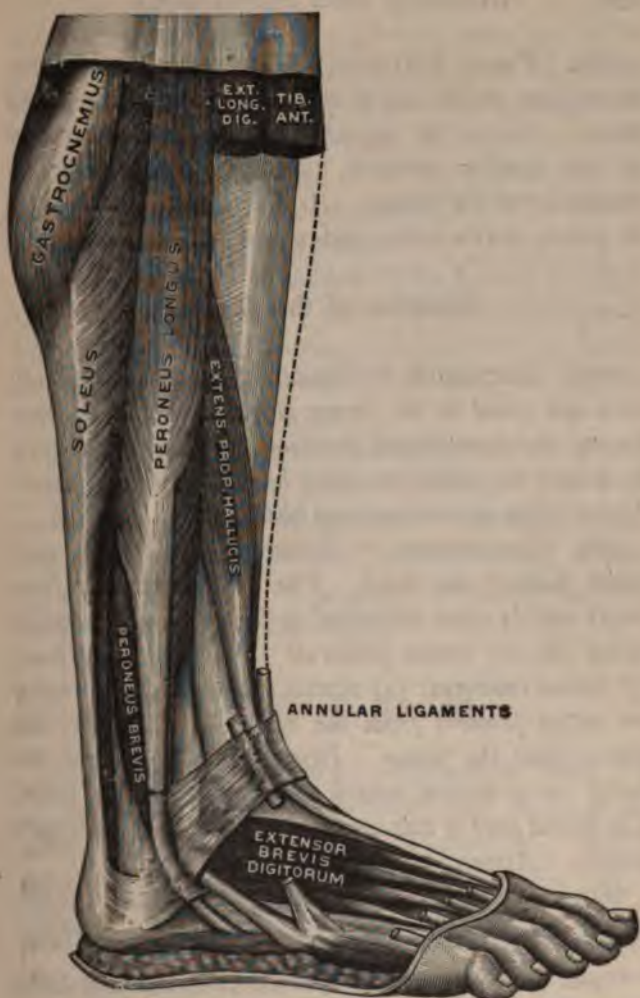

FIG. 64.—Muscles in the outer side of right leg and dorsum of foot. (Gerrish.)

286. PSOAS MAGNUS.[1]—*Situation: in the lumbar region, on the side of the spine and margin of the pelvis. Origin: the processes of the last thoracic and all the lumbar vertebræ. Insertion: in the lesser trochanter of the femur. Action: flexes the thigh on the pelvis, or vice versa, and rotates the femur outward.*

Muscles of the Thigh

287. SARTORIUS.[2]—*Situation: crossing obliquely from the front to the inner side. It helps in producing the cross-legged position sometimes assumed by tailors in sitting on their bench, hence its name. Also it helps in rotation and abduction of the thigh.*

288. QUADRICEPS.[3]—*Situation: the front and inner part of the thigh. The quadriceps has four heads and is often described as four separate muscles called the (1) rectus femoris; (2) vastus*[4] *externus; (3) vastus internus; (4) vastus intermedius. Origin: the rectus femoris from the spine of the ilium, the others from the femur. Insertion: all four are inserted in a tendon which is attached to the tibia. The lowest part of this tendon is called the ligamentum patella. Action: extension of the leg.*

289. ADDUCTORS: GRACILIS, MAGNUS, LONGUS, BREVIS.—*Situation: inner side of the thigh. Origin:*

[1] Psoas magnus. From the Greek *psoa*—loin and Latin *magnus*—great, large.

[2] Sartorius. From the Latin *sartor*—a tailor.

[3] Quadriceps. From the Latin, *quatuor*—four and *caput*—head.

[4] Vastus. From the Latin *vastitas*—vastness. (The vast external, internal, and middle muscle.)

each of the four muscles arises from some part of the os pubis. Insertion of gracilis: the inner shaft of the tibia; of the other three: the inner side of the femur. Action: the gracilis adducts the thigh, flexes the leg and rotates it inward; the other three adduct, rotate, and flex the thigh. The gracilis is a slender muscle, but it is the longest in the body.

290. BICEPS.—*Situation: in the back of the thigh. Origin: one head arises from the ischial tuberosity, the other from the posterior surface of the femur. Insertion: the head of the fibula and, slightly, the outer tuberosity of the tibia.*

291. SEMITENDINOSUS AND SEMIMEMBRANOSUS.—*Situation: the back part of the thigh, toward the inner side. Origin: the ischium. Insertion: upper and inner part of the tibia. Action: they flex the leg on the thigh—i. e., bend the knee, rotate the leg inward, and extend the thigh.*

Muscles of the Leg

292. TIBIALIS ANTICUS.—*Situation: outer side of the tibia. Origin: tuberosity and shaft of the tibia. Insertion: underside of the great toe. Action: flexes the ankle-joint, rotates the foot inward, abducts the foot.*

*293. EXTENSORS.—*There are two so named. Situation: front surface of the leg. Origin: one from the fibula, one from the tibia and fibula. Insertion: the phalanges of the toes. Action: they extend the toes, flex the ankle, and abduct the foot.*

294. POPLITEUS.—*Called also the ham muscle. Situation: behind the knee-joint and upper part of the leg. Origin: external condyle of the femur. Insertion: the tibia. Action: flexion and inward rotation of the leg.*

*295. GASTROCNEMIUS.[1]—*The calf muscle of the leg. Situation: back of the leg. Origin: outer side of external condyle of the femur. Insertion: in the tendon Achillis, which attaches it to the heel. Action: extension of the foot and, when the ankle joint is fixed, extension of the leg.*

296. SOLEUS.[2]—*Situation in the back part of the leg, in front of the gastrocnemius. Origin: upper part of the fibula. Insertion and action: the same as the gastrocnemius.*

*297. FLEXORS.—*There are seven. Situation: back part of the leg or sole of the foot. Origin: one in the fibula, two in the tibia, two in the heel, two in the under surface of the metatarsal bones. Insertion: in the toes by means of long tendons. Action: flexion of the toes.*

298. PERONEUS[3] OR PERONEAL MUSCLES.—*Situation: one on the anterior and two on the outer surface of the leg and sole of the foot. Action: extension and abduction of the foot and elevation of its outer edge.*

[1] From the Greek *gaster*—the belly and *kneme*—the leg. The muscle was so named because of its shape.

[2] Pertaining to the sole.

[3] From the Greek *perone*—fibula; so called because they cover the fibula.

Muscles of the Foot

*299. EXTENSORS.—*The extensor muscle of the toes situated on the dorsum or top of the foot. Origin: os calcis and anterior annular ligament. Insertion: the phalanges or toes. Action: extension of the toes.*

*300. ABDUCTORS AND ADDUCTORS.—*Situation: sole of the foot. Origin: tarsal or metatarsal bones. Insertion: about the same as the abductors and adductors of the fingers. Action: abduction or adduction of the toes.*

301. ANNULAR[1] LIGAMENTS.—*There are three important ligaments on the front and sides of the ankle, known as the anterior, interior, and external annular ligaments, which bind down and act as a stay to the tendons passing to the foot and toes. These ligaments are of great importance to the proper action of the tendons.*

[1] Annular. From the Latin *annulus*—a ring.

CHAPTER VII

NERVE TISSUE AND THE NERVOUS SYSTEM[1]

Characteristics of Nerve Tissue. Parts Composing the Nervous System. Division of the Nervous System into Cerebro-Spinal and Sympathetic Systems. Nature and Parts of Nerve-Cells. Nature and Function of Dendrites, Axons, Collaterals, and Nerve-Fibers. Medullated and Non-Medullated Nerve-Fibers. Sensory and Motor Fibers. Reason for Difference in Impulse Carried by Sensory and Motor Fibers. Nature and Function of Nerve-Endings. Reaction of the Sensory Nerve-Endings to Different Kinds of Stimuli. Nature and Function of Neuralgia. Arrangement and Distribution of Nervous Tissue. Plexuses. Nature of Respiratory and Other Centers. Central Connections of the Nerves. Origin and Nature of Nerve Impulse. Function of the Cell-Body. Reflex Action. Automatism. Origin of Voluntary Impulses. Degeneration and Regeneration of Nerves. Effect of Fatigue, etc., on Cell Bodies. Knee-Jerk.

THE next tissue to be considered is that which forms the main substance of the organs comprising the nervous system, viz.: nervous tissue.

[1] In the study of anatomy and physiology it is impossible to go into the detail of any one system without constantly referring to some of the others. This is more especially true of the nervous system, the functioning of all the organs of the body being dependent upon it. As it must be referred to so constantly, and as some knowledge of its nature is necessary in order to understand the references, it seems well to take up its study, with the exception of the organs of special sense, before that of the other systems and not, as is generally done, afterward.

302. This tissue is more highly specialized and its action is more wonderful than that of any other tissue in the body, for it controls human thought and conduct, it gives us the power to perceive and appreciate the world about us; to hear, to see, to move, to talk; the ability to react to our surroundings; also it controls and ensures co-ordination in the working of both the viscera and the skeletal muscles.

303. CHARACTERISTICS OF NERVE TISSUE.—These are irritability and conductivity. By irritability is meant, as in the case of muscular tissue, the power to respond to stimulation; by conductivity, the power to transmit the stimulus or, as it is often called, nerve impulse, to muscles, glands, etc. The nature of this impulse will be discussed later.

304. PARTS COMPOSING THE NERVOUS SYSTEM.—The nervous system consists of the following parts: (1) Large masses of nerve tissue situated within the skull and the spinal column and constituting the brain and spinal cord; (2) smaller masses of ganglionic tissue, situated for the most part in the abdominal and thoracic cavities, but also in the neck and head, and constituting what are known as sympathetic ganglia; (3) nerve-fibers which connect the brain, cord, and sympathetic ganglia with each other, the periphery [1] and the viscera; (4) modifications of the peripheral terminations of the nerves which constitute

[1] Periphery, the outside or superficial portions of a body.

the organs of the external senses, as the eye, ear, tactile corpuscles, etc.

305. Division of Nervous System into Cerebro-Spinal and Sympathetic Systems.—For convenience in description the nervous system is divided into two parts, which are usually spoken of as the *cerebro-spinal system* and the *sympathetic system.* These two parts, do not, as the names might imply, constitute two different systems, for, both anatomically and functionally, they are very dependent upon each other and, with a few differences to be discussed in this and the following chapter, very similar.

306. The so-called **cerebro-spinal system** consists of the brain, the spinal cord, and their nerves, which are known as (1) the cerebro-spinal nerves, (2) the cranial nerves; (3) the spinal nerves. The first set of nerves are those connecting the brain and the spinal cord; the second, those passing to and from the brain through openings in or between the bones of the skull, but not becoming part of the spinal cord; the third, those nerves extending between the spinal cord and the periphery.

307. **The sympathetic system** consists of masses of nerve cell-bodies known as ganglia, situated for the most part, as previously stated, in the abdominal and thoracic cavities, and the nerves connected with these ganglia.

To understand the structure and working of the nervous system, it is necessary to know something

of the nature of nervous tissue. We will therefore take up the study of the tissue first.

308. NERVE TISSUE.—The tissue composing the nervous system is different in some respects from that of any other tissue of the body. Like other tissues, however, its unit is a cell, and the cell consists of cytoplasm with nucleus, nucleolus, and, in some cases, a centrosome; but the structure of the cell and the nature of its cytoplasm is not exactly like that of the cells of other tissues, and there are even differences in the cytoplasm of some of the nerve cells.

309. NERVE CELLS.—Names of different parts: Nerve cells, or, as they are also called, neurones, may be said to consist of:

1. A cell-body.
2. Cell-processes.

310. The names of processes and their different parts are:

(1) Dendrites or dendritic processes.

(2) Axis-cylinder processes known also as neuraxons, or axons.

(3) Collaterals (branches of axons).

(4) Nerve-fibers (continuations of axons).

(5) Nerve-endings.

311. NUMBER OF PROCESSES OF A CELL.—The number of processes or poles extending from the cell-bodies varies, and when there is but one the

cell is said to be *unipolar;* when there are two it is known as a *bipolar cell;* when there are more than

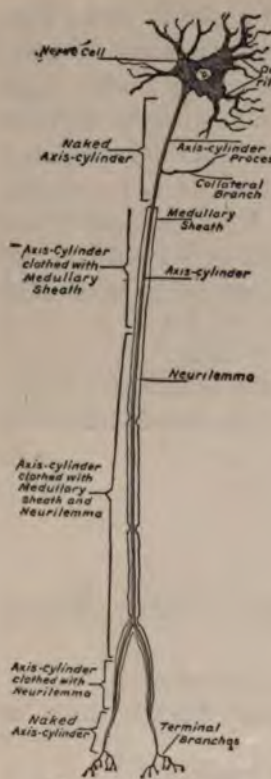

FIG. 65.—A neurone.

FIG. 66.—A neurone from the cerebral cortex. The axis-cylinder process, dendrites and collaterals are marked 1, 2, and 3, respectively. The neuraxon is shown in the drawing only for a short distance. If the entire length were pictured it would run a long way below the bottom of the page. Very greatly magnified.

two, as a *multipolar cell.* One process is always an axon.

312. DENDRITES.[1]—The dendritic processes,

[1] From the Greek *dendrone*—a tree.

almost immediately upon emerging from the cell-body, break up into a series of fine branched filaments that divide and subdivide and spread out in various directions, like the branches of a tree. The majority of dendrites proper are short and the structure of these is similar to that of the cell body. They serve to receive impulses from the axons of other cells and to transmit them to their own cell bodies. The processes of different cells do not anastomose, but are in very close proximity. Their juncture is termed their *synapsis*.

313. THE AXIS-CYLINDER.—The axis-cylinder —known also as the *neuraxon or axon*—is usually of some length. It terminates either in an arborization like the dendrites or else merges into what is known as a nerve-fiber.

314. SENSORY NEURONS.—The processes of certain cells known as *sensory neurones* differ somewhat from those just described—a single axon extends from each cell-body for a short distance and then forks, giving rise to two branches, one of which extends to the periphery and the other—the axon—into the spinal cord. The branches extending outward to the periphery are by some classed as dendrites, because they carry impulses to their cell-bodies, but, though these processes perform the function of dendrites, their structure is similar to the axons and, like them, they acquire a sheath. Thus, they are more commonly considered as nerve-fibers and are known as *sensory nerve fibers*.

315. NERVE FIBERS.—These are of two kinds:

medullated or *white fibers* and *non-medullated* or *gray fibers.*

316. *A medullated fiber* is composed of three parts: (1) an external sheath called the sheath of Schwann or the neurilemma[1]; (2) a white, semi-solid substance known as the *medullary*[2] or *myelin sheath* or the *white substance of Schwann*, to which the peculiar opaque, white appearance of the medullated nerves is due; (3) the axis-cylinder, a continuation of the axis-cylinder process.

317. Nature of Neurilemma and Nodes of Ranvier.—The neurilemma is a delicate, structureless membrane in which nuclei are placed at intervals. It corresponds to the sarcolemma investing muscle fibers. In most medullated fibers the neurilemma has ring-like constrictions at regular intervals which divide the fibers into a series of links. These constrictions are due to interruption in the continuity of the white medullary substance, in consequence of which the neurilemma sinks inward and comes in contact with the axis-cylinder. These constrictions are called the *nodes of Ranvier.* The interval between the nodes are known as the internodes. As the nerve-fibers approach their terminations, they lose first their medullary sheath and then their neurilemma, leaving the bare axis-cylinder.

318. Function of Medullary Sheath.—The myelin or white substance of the medullated

[1] From the Greek *neuron*—a nerve and *lemma*—a coat.
[2] From the Latin *medulla*—marrow. Resembling marrow.

nerves serves as a protection to the axis-cylinder, and some physiologists think that it may possibly act as a non-conducting medium to prevent nerve impulses being deflected from their intended course before they reach their terminations.[1]

319. Function of Nodes of Ranvier.—The nodes of Ranvier are supposed to exist for the purpose of permitting the passage of blood-plasma[2] into the axis-cylinder in order to help supply it with nutriment.

320. Non-Medullated Nerve-Fibers.—The non-medullated fibers, which are also known as the fibers of *Remak*, differ from medullated fibers in not possessing a medullary sheath, and therefore having a grayish color, and in being smaller, being only about ½ to ⅓ as large in their course within the trunks and branches of the nerves. Non-medullated nerve-fibers constitute the principal part of the branches and trunks of the sympathetic nerves, the whole of the olfactory nerve,[3] and they are mingled in various proportions in the cerebro-spinal nerves. In the fetus, during the early stages of development, all the nerve-fibers are non-medullated.

321. Functions of Nerve-Fibers.—The office of nerve-fibers is to conduct nerve impulses. Impulses pass to the brain and spinal cord from the periphery, including the viscera, and from the brain and cord to the periphery. Fibers carrying

[1] See paragraph 321.
[2] See paragraph 454.
[3] The nerve connected with the sense of smell.

impulses in the first direction are spoken of as *sensory*, or *afferent*,[1] or *centripetal*[2] fibers. They are called sensory because it is to them that sensation is due, and afferent and centripetal because the impulse travelling over them is going toward the center. Fibers carrying impulses from the cell-body to the periphery or viscera are known as *motor*, *efferent*,[3] and *centrifugal*[4] *fibers*. They are called motor, because the impulses which they convey cause functional activity—*e. g.*, a muscle contracts, a gland secretes; and efferent and centrifugal, because they carry impulses out from the center.

322. Reason for Different Results of Nerve-Impulses.—The present theory is, that known as the *Müllerian doctrine;* this is that impulses vary only in intensity, not in kind, and produce one effect or another according to the particular structure on which they finally act; *e. g.*, it is thought that the impulses passing over the optic nerves and those passing over motor nerves are the same, but, because the optic nerves stimulate a certain portion of the cerebral cortex (paragraph 356), we see, and because motor nerves stimulate muscle, muscular contraction results. It is the peripheral endings of the sensory fibers that are adapted for stimulation, and the central [5]

[1] From the Latin *affero*—to bear to.
[2] From the Latin *centrum*—the center, and *petere*—to seek.
[3] From the Latin *effero*—to bear out.
[4] From the Latin *centrum*—the center, and *fugere*— to flee.
[5] In the nerve centers, the brain, spinal cord, or ganglia.

endings of the motor fibers; the motor fibers being stimulated by impulses transmitted from the sensory fibers. The arrangement of the nerves whereby this transmission is made possible is shown in paragraph 333.

323. NERVE ENDINGS.—Towards their termination, the medullated nerve-fibers lose their neurilemma and their myelin sheath, leaving the bare axis-cylinder, which ends in different ways. Thus, at the periphery, the sensory nerve-fibers end in three different ways: (1) they divide and subdivide into minute branches called *interepithelial arborizations*,[1] which pass among the epithelial cells of the skin, mucous membrane, secretory glands, etc.; (2) they end in small, variously shaped bodies called tactile corpuscles[2]; the nerve-fibers connected with the sense of touch all end in this way; (3) in the organs of special senses—*e.g.*, the eyes, ears, etc.; the axis-cylinders, after dividing and subdividing into fibrils, enter and terminate in highly specialized epithelial cells. These cells will be further described in the chapters devoted to the sense organs.

324. The axis-cylinders of motor fibers supplying the skeletal muscles, at their peripheral termination, break up into minute fibrils that, in the form of flattened granular masses, known as *motor plates*, are attached to the sarcolemma of muscle fibers.

[1] Arborization. From the Latin *arbor*—a tree.

[2] It is thought that the different-shaped corpuscles are of a somewhat different nature, and that possibly they may react to different kinds of stimuli.

Motor plates transmit stimuli from the nerve fibers to the muscle fibers. Owing to the number of fibrils arising from one fiber as many as 100 muscle fibers may be influenced (*i. e.*, made to contract) by the stimulus passing over one nerve fiber, but, as the muscle fibers are very minute, even 100 form but a small part of a muscle and thus many neurones are concerned in the contraction of even small muscles. Axis cylinders that end in the gray matter (paragraph 330) and their collaterals terminate chiefly in fine filaments known as *arborizations*.

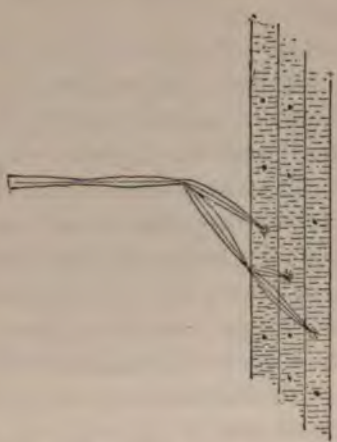

FIG. 67.—Showing attachment of nerve and muscle fibers.

325. The non-medullated motor nerve-fibers of the sympathetic system end chiefly in plexuses, see paragraph 328.

The terminations of the dendrites and collaterals have been already described in paragraphs 312 and 314.

326. NEUROGLIA.—This is a form of connective tissue consisting mainly of cells that give off numerous fine processes which extend in every

direction and intertwine among the nerve-cells and fibers. It is found to some extent in all parts of the brain and spinal cord and serves to support and to hold nerves, blood-vessels, etc., together.

327. Nature and Distribution of Nerves.—The nerve-fibers are collected into bundles and, with their blood-vessels, held together by connective tissue. These bundles are known as *nerves* or *nerve trunks* or, certain ones in the spinal cord and brain, as *tracts*. Also, as will be seen in the description of the brain, there are masses of nerve-fibers known by special names. These masses and tracts of nerve-fibers constitute what is known as the *white matter* of the brain and cord. As the nerves, tracts, etc., consist of nerve-fibers, their function is that of the fibers; thus, they serve for the passage of nerve impulses between the brain, spinal cord, and ganglia and between these and the periphery, including the viscera. The majority of nerves are what are known as *mixed nerves—i. e.*, they contain both motor and sensory fibers, but, as impulses are discharged only at the final terminal of the fibers, those passing along one fiber never interfere with other fibers.

328. Plexuses.—At certain parts of their course many of the nerves form plexuses or networks in which they anastomose with each other, some of the fibers of one nerve passing into another nerve and continuing with its fibers. The objects of such interchange of fibers are: (1) to give to each nerve passing off from the plexus a

wider connection with the nerve-centers than it would have if it proceeded to its destination without such communication with other nerves; (2) each nerve is less dependent on the integrity of any single portion of a nerve-center or nerve-trunk, (3) any given part, say a limb, is less dependent upon the integrity of any one nerve.

329. Branching of Nerves.—In a great many cases the fibers of a nerve branch off from the main bundle and go to supply muscles and viscera quite distant from each other.

330. Nature and Distribution of Gray Matter.—The so-called *gray matter* of the nervous system consists of the nerve cell bodies, dendrites, non-medullated axis-cylinders and their collaterals. It is found massed in certain parts of the brain and spinal cord and also constitutes the ganglia.

331. Nature of Nerve Centers and Ganglia.—By a nerve center is meant a mass of gray matter concerned with a particular function: for example, the respiration is controlled by a certain mass of gray matter known as the *respiratory center;* the caliber of the blood-vessels is controlled by masses known as the *vasomotor centers;* swallowing is controlled by a mass known as the *deglutition center.* It is thought that most of the motor and secretory activities of the body are controlled by special centers. Ganglia are small, detached masses of gray matter found in parts of the brain and other locations, see paragraph 424.

332. Adjustors or Correlation Centers.—

The sensory and motor neurones do not, as a rule, connect directly with each other at their central terminations, but have neurones with, usually, short, branching axons intercalated between them. Such neurones are known variously as *correlation centers, association units and adjustors.* By means of these, a number of efferent neurones are influenced by a single sensory impulse and thus a single sensory impulse can influence many peripheral structures and be transmitted, via cerebrospinal nerve-fibers to the brain. For example, when nerve endings in the skin that are affected by cold are stimulated, the impulses pass to the motor centers which cause contraction of the skeletal muscles, to those which cause constriction of the blood-vessels (vasoconstrictor centers), to the respiratory center, and to parts of the brain which, when stimulated, produce a consciousness of cold.

333. SINAPSES.—As previously stated, the processes of different cells are not in actual continuous connection with each other. Nevertheless, under normal conditions, sensory impulses can pass readily from the axons of sensory neurones to the dendrites of motor neurons or to those of adjustors. The point where impulses pass from the processes of one cell to those of another is known as a *sinapse.* The sinapses are thought to have several important functions: (1) They act as valves, *i. e.*, they make it impossible for impulses to reverse their direction and return over the fiber which

transmits them. (2) The sinapses, it is thought, take an important part in the regulation of the readiness with which impulses pass from cell to cell. Under normal conditions, there is a moderate degree of inhibition to the passage of impulses at the sinapses; under certain conditions, as in some states of fatigue or by the influence of alcohol, hypnotics, and certain other drugs and certain diseased conditions, this inhibition or, as it is often termed, *central resistance* is raised or increased and the individual does not respond readily to stimuli. On the other hand, with caffein (*e. g.* coffee), strychnin, and drugs with similar action, the poisons produced in certain diseases—*e. g.*, tetanus, some stages of fatigue and other conditions which produce the state designated as *nervous*, the individual responds too readily to stimuli, *e. g.*, he is easily irritated, jumps if he hears a sudden noise, or in other ways shows a lack of inhibition of stimuli.

334. Functions of the Cell-Body.—Important functions of the cell body are: (1) The nutrition of the cell; the whole neurone dies if the cell-body is destroyed. (2) Cell-bodies act as transmitters of nerve impulses and, possibly, reinforce the energy which they transmit to other cells. The cell-bodies are often likened to the chemical battery of the electric circuit used for door bells and the like. (3) The cell-bodies probably take an important part in the various properties manifested by the gray matter of the brain and cord.

335. Functions of Gray Matter.—It is in the gray matter: (1) That transmission of impulses from sensory to motor fibers takes place; (2) that impulses are modified, *i. e.*, inhibited, as described in paragraphs 333, and 343, or strengthened, as by the action known as *summation* in which a number of impulses entering a nerve-center from similar or different sources are combined into one effective impulse before transmission to motor nerves; (3) that the greater part of the nourishment needed by the neurone is absorbed by the dendrites and cell-bodies. (4) The gray matter of certain parts of the brain is an important factor in all functions concerned with consciousness.

336. Nature of Nerve Impulses.—This is unknown. At one time, it was thought that the nerves were tubes and that the *activating spirit*, called *nerve-juice*, flowed through them. After the electric current was obtained, nerve impulse was thought to be similar to this, but electricity travels at the rate of 186,000 miles per second and the rate of nerve impulses varies, but is about 27 meters per second; also there are other differences between the two. Nerve impulse has also been thought to be of a vibratory nature, such as the molecular vibration characteristic of heat conduction through matter, but neither is it like this in all respects, and it has been shown that as the result of their activity chemical changes occur in cell-bodies which cause the decomposition of some of their substance; so it is thought that, chemical

energy takes some, though probably but a small, part in the form of energy known as *nerve impulse.*

337. Reaction of Sensory Neurones to Different Kinds of Stimuli.—All sensory nerve-endings are not affected by the same kind of stimulus, nor do they react to stimuli in the same way. Thus, some nerve-endings in the skin are affected by heat, others by cold, others by pain, etc.; the auditory nerve-endings are affected only by sound. Nerve-centers that are stimulated in more than one way usually respond in a similar manner to the different stimuli, *e. g.*, the vision center is stimulated by the action of light on the optic nerve, but a blow on the head or spinal column may produce a sensation of light.

338. Nature of Reflex Action.—By reflex action is meant involuntary activity produced as the result of stimulation of motor fibers by impulses transmitted from sensory fibers.

339. Examples of Reflex Actions.—The majority of the movements of our bodies, whether due to the action of the voluntary or involuntary muscles, are reflex. Examples of reflexes are: when food is taken into the mouth the sensory nerves are stimulated, and they carry impulses to the nerve-centers controlling the secretion of the saliva, of mastication, of deglutition; consequently impulses are sent along the motor nerves of the muscles and glands concerned in these activities. Irritating food or poison in the stomach may send impulses along certain sensory nerves to the center in a

part of the brain known as the medulla oblongata, from which impulses are sent along motor fibers back to the stomach, abdominal muscles, etc., which produce vomiting. If a person is plunged into a cold bath, such nerve-endings in the skin as react to cold are stimulated, and the impulse resulting from this stimulus will be transmitted: (1) to motor nerves which cause contraction of the skeletal muscles; (2) to one of the sets of nerves supplying the walls of the peripheral blood-vessels, called from their action the vasoconstrictors[1]; (3) to the nerves supplying the muscles of respiration. The colder the water and the more sudden its application, the quicker and stronger will be the reflex response.

340. Reflex Actions may or may not be Associated with Consciousness, but, when they are, the consciousness is quite incidental to the reflex and comes after the action; *e. g.*, if the hand touches a hot stove, the owner is conscious of pain, but the hand was withdrawn before consciousness was awakened. Movements which have become reflex are often better performed when not associated with consciousness and may even be interfered with or awkwardly performed when consciousness is aroused.

341. **Some movements that are at first volitional later become reflex**—*e. g.*, walking, dancing riding, etc. "*In learning such movements, one must, as the saying goes, establish his reflexes, and*

[1] From the Latin *vas*—a vessel

the result can hardly be understood otherwise than by supposing that the continual adjustment of certain sensory impulses to certain co-ordinated movements results in the formation of a more or less complex reflex arc."[1]

342. NATURE OF REFLEX ARC.—By a reflex arc is meant the pathway over which the impulses travel. The simplest form of a reflex arc consists of a sensory neuron, an adjustor, and a motor neuron. There are very few reflex actions carried out by such a simple arc as this, however; *e. g.*, even in such a simple action as walking, sensory impulses, due to stimulation of nerve endings in the feet and moving muscles, go to the spinal cord and affect, not only motor neurons which send impulses from there, but also transmit impulses to different parts of the brain which are concerned with the maintenance of balance and the action of the muscles used in walking, and from these parts also motor impulses are sent to the muscles involved in walking. A single reflex may start a succession of co-ordinated movements,—"*e. g., if the sole of the foot of a sleeping person be tickled, the leg is*

FIG. 68.—Schema to show connection between motor neuron and adjustor and sensory neuron in spinal cord—a reflex arc.

[1] *Text-Book of Physiology*, page 152. Howell, Saunders & Co.

drawn up, and after an interval is again straightened out. The return to the straight position is not merely a passive falling back of the limb, but is an orderly movement, showing that the first reflex has initiated a second reflex producing an opposite effect. A similar phenomenon occurs in the reflex movements of ordinary walking."[1]

343. INHIBITION.—Some of the centers and ganglia which send impulses to the viscera inhibit their action and, sometimes in doing so, act against impulses sent from other centers. Thus, stimulation of inhibitory centers will retard the functioning of glands and other organs, and their depression will cause increased activity of the organs.

344. DIFFUSION OF IMPULSES.—Very strong stimulation of certain nerve-centers may cause diffusion of impulses—*i. e.*, the impulses are passed over more reflex pathways than are usually involved in any one variety of stimulation. This is what happens in convulsions.

345. AUTOMATISM.—Another function possessed by certain nerve-centers and also by the tissue of the heart is that which is known as *automatic action* or *automatism*. By this is meant that such a center or tissue is not dependent for its activity upon any afferent stimuli from the outside, but that the stimuli which excite it to activity arise within itself. This action differs from reflex

[1] *The Nervous System*, page 18. J. D. Lickley, M. D. Longmans, Green & Co.

movements in that it is rhythmical; it will be referred to again in connection with the heart and the respiratory movements.

346. HABIT.—Even much more complicated actions than those referred to under reflexes come in time to be performed almost, if not quite, without consciousness, by adjustment of the nervous mechanism, due to constant repetition of acts. Such actions, if peculiar to the individual, are *termed habits*, to distinguish them from reflexes, which are common to all normal individuals of the same species. The habits of an individual are determined chiefly by inherited characteristics, environment, the frequency of performing actions in the same manner.

347. EFFECTS OF FATIGUE UPON THE NERVOUS SYSTEM.—In paragraph 220 it was stated that muscular contraction gave rise to substances known as *fatigue poisons*. As these are absorbed by the blood, they affect structures distant from the moving muscles and among others those of the nervous system. Excessive amounts of these poisons; also, toxic substances formed in the intestine, as the result of excessive putrefactive processes, and absorbed by the blood; the constant over-excitation of nerve-centers by such causes as worry, grief, pain, injury to nerves, even without the association of pain—as in an operation under anesthesia—have all been found to produce changes in the nerve cell-bodies. Toxic substances and changes in the cell-bodies, experiments seem

to show, may affect the motor nerve-endings and the sinapses, but nerve-fibers seem to suffer less than other parts of the neurone. The conditions thus produced upon the nervous system result in impairment of its functioning; the powers to reason, to concentrate the attention and similar faculties are lessened, while some parts of the nervous mechanism are over-irritable and respond too readily or to too great an extent to stimuli, and the sinapses may not inhibit the passage of impulses to a normal degree. Thus slight stimulation of sensory nerve-endings, that might not even be noticed under ordinary circumstances, give rise to discomfort and even pain. Since the centers are constantly over-stimulated in this way, they are over-ready to send impulses along motor nerves and the individual is restless, excitable, easily irritated, and, as the inhibitory centers are also likely to be over-stimulated, they may interfere with the functioning of the viscera so that defective digestion, constipation, and other disorders result. A state of nerve-fag may vary in intensity from a slight temporary fatigue that will be recovered from during the night's rest and in which only a few of the symptoms just described are present to a condition that will take several months for recuperation. Indispensable for recovery from such a condition are: sufficient rest, the removal of the exciting cause of the disorder, fresh air, and nourishing food.

348. Nerve Regeneration.—Since it is the

cell-bodies that supply nutrient for nerve-fibers, if a nerve outside the brain or cord is cut, or otherwise destroyed, the portion of the fibers on the peripheral end of the injury will disintegrate, but if the cell-bodies are intact the fibers will grow again from the central end, along their original tract. Nerve-fibers within the brain or cord seldom recuperate if severed from their cell-bodies.

349. Use of Knee-Jerk in Diagnosis.—A common means used by doctors to ascertain if a patient's nerve-centers are intact is the so-called *knee-jerk*. This consists in flexing one of the patient's legs so that the quadriceps muscle will be under tension, and then tapping lightly below the knee-cap. If the patient's nervous system is normal the foot usually gives a light jerk, due to contraction of the quadriceps muscle; but if there are lesions in certain parts of the spinal cord there will not be any response, as the passage of either the sensory or motor impulses are interfered with—which ones depending upon the location of the trouble. On the other hand, abnormal conditions in other parts of the cord or some parts of the brain may allow of an increase in the force of the jerk by cutting off or weakening the inhibitory influence that certain parts of the brain have on spinal reflexes.

CHAPTER VIII

NERVOUS SYSTEM—*Continued*

The Brain

Location, Weight, Ventricles, Main Divisions of Brain. The Cerebrum: Arrangement of Gray and White Matter, Tissues, Convolutions or Gyres, Lobes, Function, Localization of Function. Nature, Location, and Function of Motor Area, Sensory and Association Areas. The Mesencephalon or Midbrain: Location, Structure, and Function. The Cerebellum: Location, Divisions, Arrangement of Gray and White Matter, Function. The Pons Varolii: Location, Appearance, Structure, and Function. The Medulla Oblongata: Location, Divisions, Decussation of Nerves in Medulla, Function, Reflex and Automatic Centers. Membranes Covering the Brain: Names and Nature.

HAVING considered the nature and function of nerve tissue we shall proceed to study the structure of the system of which the tissue forms the principal substance and shall begin with the brain.

350. LOCATION OF THE BRAIN.—The brain[1] or encephalon[2] is that portion of the cerebro-spinal

[1] From the Greek *bregma*—the upper part of the head.

[2] From the Greek, *engkephalus*—within the head.

NOTE. In describing the brain and spinal cord it is almost impossible to avoid mentioning names which are not necessary for nurses to remember. Those that are will, therefore, be starred.

nervous system which is contained in the cranial cavity.

351. Weight of the Brain.—The human brain is heavier than that of any of the lower animals excepting the elephant and the whale. The prevailing weight of the brain in the human adult male ranges from 46 to 53 ounces, the average being about 49½ ounces, or a little more than three pounds. That of the female ranges between 41 and 47 ounces, the average being 44 ounces. The brain increases in weight rapidly up to the seventh year, more slowly to between sixteen and twenty, and still more slowly to between thirty and forty, when it reaches its maximum weight. Beyond this age the weight decreases slowly, about an ounce each ten years.

352. Formerly it was thought that the size of the brain corresponded to the intellectual capacity of the individual, but this is certainly not always the case, for some individuals who have never shown any remarkable capacity have had very large brains.

353. Ventricles of the Brain.—The brain is not a solid mass, for, as can be seen in Fig. 69, there are in its interior a series of connected cavities called *ventricles.** The two known as the lateral ventricles are the largest. These, as can be seen in Fig. 69, are situated one in each half or hemisphere (see paragraph 360) of the brain. They are connected with one another and with the third ventricle by a small opening called the

foramen of Monro.[1] In the septum, or wall dividing the lateral ventricles, is a cavity which does not connect with the other ventricles, this is known as the fifth ventricle. The third ventricle is connected, as can be seen in Fig. 69, with the fourth ventricle by the small tube-like canal known as the *aqueduct of Sylvius.*[2] The fourth ventricle is the space between the posterior surface of the medulla oblongata[3] and pons[3] in front, and the cerebellum[3] behind. It is continuous with the canal, known as the *central canal*, which traverses the entire length of the spinal cord.

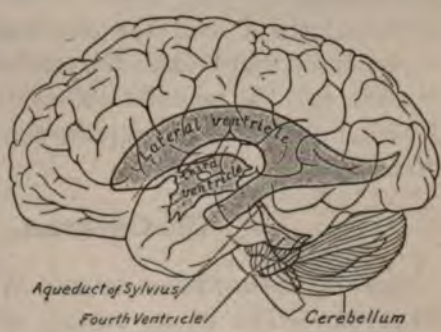

FIG. 69.—Scheme showing relations of the ventricles to the surface of the brain.

354. The ventricles and central canal are lined with a serous membrane which secretes a serous fluid. In health the amount of fluid is small, but in certain diseases of the brain, as meningitis, the amount is much increased, and is present not only in the ventricles but all through the substance of

[1] Name of a famous anatomist.
[2] *Ibid.*
[3] See paragraphs 389, 385, 380.

the brain, and the symptoms of the disease are partly due to pressure by this fluid on the nerve tissue. The cause of this increased quantity of fluid is the same as that of the exudation of fluid into the tissues in inflammatory conditions of other parts of the body. This is discussed in paragraph 469.

355. Main Divisions of the Brain or Encephalon.—The brain is divided into five principal parts, viz: the cerebrum[1]—the mesencephalon or mid-brain—the cerebellum,[2] the pons Varolii, and the medulla oblongata. The relative location of these various parts can be seen in Figs. 70 and 71.

The Cerebrum

356. Arrangement of the White and Gray Matter.[3]—The entire surface of the cerebrum, both upper and under, is composed of layers of gray nervous tissue which is of variable thickness in different parts. This is called the cortex,[4] because like the cortex—bark—of a tree it forms a covering. There are also four masses of gray matter, two on either side, at the base of the cerebrum. These are the *two thalami* (sing. *thalamus*[5])

[1] Latin *cerebrum*—the brain.

[2] Latin *cerebellum*, a little brain.

[3] It will be remembered that the gray matter consists of all bodies, dendrites, axons, and non-medullated nerve-fibers.

[4] Latin *cortex*—the bark.

[5] From the Greek *thalamas*—a bed-chamber. In anatomy the word means the place where a nerve originates.

and the *corpus striatum.*[1] Between the layers of gray matter and between the cells of each layer are gray and white nerve-fibers running in all directions and supported by neuroglia. The bulk of the white matter, however, is in the interior of the cerebrum. It consists of a close network of medullated fibers which link the different parts of the brain together and connect the brain with the spinal cord.

FIG. 70.—Semidiagrammatic view of the cerebro-spinal axis, left side. (Gerrish.)

357. FISSURES AND CONVOLUTIONS OF THE CEREBRUM. —In the young fetus the cortex is smooth and uncreased, but as months go by it becomes wrinkled, narrow depressions occurring all over it and getting deeper and more numerous with its development both

[1] From the Latin *corpus*—a body and *stria*—a streak. So called because of its striated—striped—appearance, due to the intermingling of numerous white fibers with the gray matter.

during intra-uterine life and after birth. On the other hand, as old age advances the ridges, known as *convolutions* or *gyri*,[1] between the depressions undergo atrophic changes, and the depressions, consequently, grow less marked. Their size and number vary greatly in different brains.

358. These creases are infoldings of the cortex, and, consequently, the more numerous and deeper they are the greater is the amount of the peripheral gray substance and the larger the extent of surface for the termination of the white fibers. The deeper depressions are called *fissures* and the more shallow ones *sulci*.[2]

359. Total Fissures.—Some fissures are much deeper than others, and those in which the depression extends almost through the entire thickness of the brain wall are called *total fissures*. The principal ones are:

(1) *The Great Longitudinal Fissure.*—This extends from the back to the front of the cerebrum and divides it into two hemispheres which are held together by a wide band consisting of white or medullated nerve-fibers. This band is known as the *corpus callosum*.

(2) *The Transverse Fissure* which is between the cerebrum and the cerebellum. It is half in one hemisphere and half in the other.

(3) *The Sylvian Fissure;* for location see Fig.

[1] From the Greek *gyres*—a ring.
[2] Latin *Sulcus* (pl. *sulci*)—a furrow.

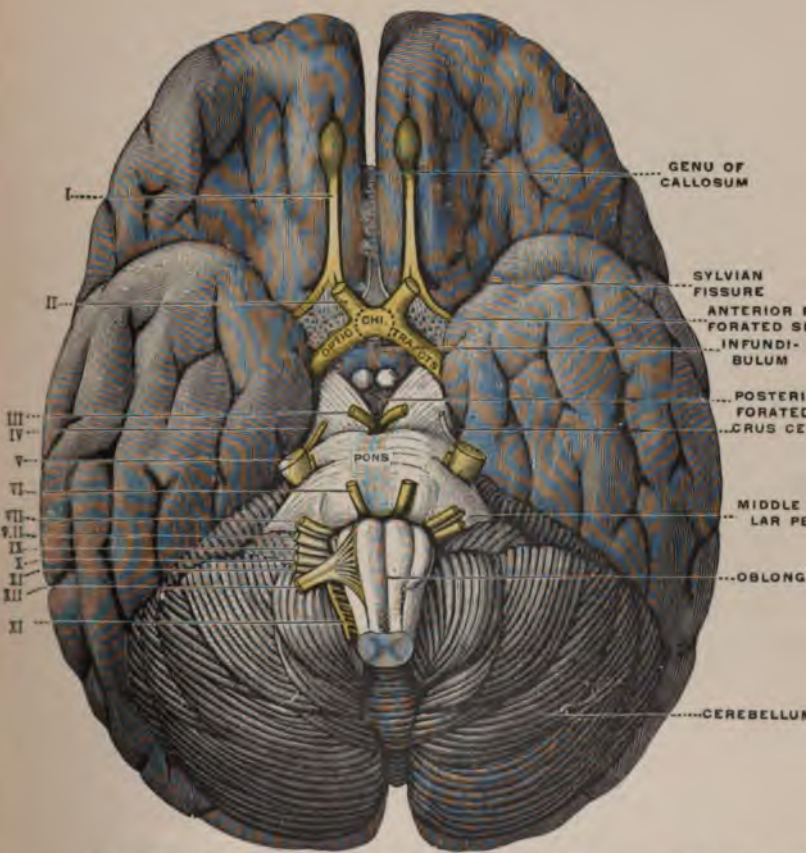

FIG. 71.—Under surface of the brain, showing the superficial origins o the cranial nerves. The Roman numerals indicate the nerves. (Gerrish.)

72. There is one in each hemisphere, as are also the two following ones.

(4) *The Rolandic* or Central Fissure;* see Fig. 72 for location.

(5) *The Parieto-Occipital Fissure;* see Fig. 72.

360. LOBES OF THE CEREBRUM.—As already stated, the great longitudinal fissure divides the cerebrum into two hemispheres, and the transverse fissure divides the cerebrum from the cerebellum. The other fissures divide the two hemispheres into lobes. The lobes, with one exception, were named from the bones of the cranium under which they lie; therefore, they are known as the *frontal*, *parietal*, *temporal*, *occipital*, and—the exception—the *central lobes*. The location of the first four can be seen in Fig. 72. The central lobe, also called the island of Reil, is not seen because it is covered by the lower ends of the frontal and parietal lobes. The lobes are the same in both hemispheres.

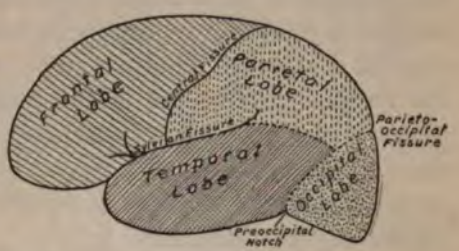

FIG. 72.—The lobes of the convex surface of the hemisphere, left side.

361. FUNCTION OF THE CEREBRUM.—In the cerebrum are situated the nerve centers which govern the phenomena of the mind and co-ordina-

tion of movements. These centers are the seat of intelligence, reason, and will, the means of retaining impressions of things and of reproducing them in ideas. They are the medium of all the higher emotions and feelings and of the faculties of judgment, imagination, memories, etc.

362. LOCALIZATION OF FUNCTION.—As the result of experiments on anesthetized animals and observation of individuals suffering from cerebral wounds or diseases, physiologists have been able to localize the special parts of the brain which control the various movements of the body and some of those concerned with secretion and sensation. Also, they have been able to gain some idea of the portions of the cerebrum concerned with the higher mental attributes.

363. NAMES OF AREAS.—The portion of the cerebrum governing the muscular movements of the body is known as the *motor area*;* those parts controlling sensation, as the *sensory areas*;* and those connected with such mental properties as reason, will, imagination, etc., as *association areas.**

364. THE MOTOR AREA.—The motor area is known also as the *Rolandic* area*, because, as can be seen in Fig. 73, it adjoins the fissure of Rolando. The various parts of the body of which the movements are controlled by nerves arising in this area, and the special portions of the area in which the nerves supplying the various parts arise, can be seen in the same figure.

365. DECUSSATION OF THE NERVES.—It must

be remembered, however, that the nerves arising in the cortex of the right side of the brain govern the movements of the left side of the body, and *vice versa*. The reason of this is that in the lower

FIG. 73.—Location of motor areas in brain of chimpanzee (Sherrington and Greenbaum). The extent of the motor areas is indicated by stippling; it lies entirely in front of the fissure of Rolando (sulcus centralis). Much of the motor area is hidden in the sulci. The regions marked eyes indicate the areas whose stimulation gives conjugate movements of the eyeballs. It is doubtful, however, whether these represent motor areas proper.

end of the medulla the nerves extending into and from the spinal cord decussate or cross. Because of this, injury to the right side of the brain will interfere with movement of the left side of the body, and *vice versa*.

366. VALUE OF KNOWLEDGE OF AREAS.—The knowledge of the location of these motor areas is of

great value to physicians and surgeons when treating patients who are subject to convulsions, or who are paralyzed as the result of pressure on some part of the cerebrum, for by observing the parts of the body involved in the convulsive movements, or in which there is loss of function, they can usually locate the exact portion of the brain that is affected. Nurses caring for patients who have convulsions must note every detail of the nature of an attack, viz: which parts of the body are involved, which are affected first and in what manner, how long an attack lasts, and the after-effect upon the patient.

367. Difference in the Functioning of the Motor Area in the Lower Animals and Man.—In birds and many of the lower animals, extirpation of the cortex of the cerebrum does not interfere with their power of movement, but only with such intelligent and connected movements as are outgrowths of past or inherited experiences. Consequently, the movements they do make are simple reflex responses. For example, a cerebrum-less pigeon, if placed on a hot plate, will lift first one foot and then the other, the ordinary reflex response to such a stimulus; but it will not fly away. Such a pigeon will be kept alive only if it is fed, for even when hungry (having forgotten the connection between hunger and feeding) it will not look for food.

368. In man, on the contrary, even the power of movement is controlled by the motor area of the

cerebrum, and disease of or injury to any portion of this area will interfere with the functioning of the part of the body supplied with nerves that have their origin in the affected part.

369. The Sense Areas.—By the sense areas is understood those parts of the brain to which sensation is due and which control vision, hearing, taste, smell, and, to some extent, speech, etc. With the exception of the speech center, the discussion of this part of the nervous system will be taken up in the chapters devoted to the sense organs—viz., the skin, eyes, nose, mouth, and ears.

370. Speech Centers—*Aphasia.*—There are four small areas in the cerebral cortex—for location see Fig. 74—known as the *speech centers*, because injury to them results in some form of inability to speak or to write or to understand spoken or written language; which form of the trouble, depending upon the location of the injury. These centers are not connected with nerves that cause muscular contraction nor with the nerves of sight or hearing, but are what are known as *memory centers*. Thus, the inability to speak as usual, or to write or to understand words is not due to any paralysis or loss of vision or hearing, but to loss of memory of words or of how to form letters or of the meaning of words seen or heard. How these areas do control the memory of such things is not known. Such loss of memory is known as *aphasia*. When the trouble is connected with speaking and writing it is known as *motor*

aphasia, and inability to understand speech or to read is often termed *sensory aphasia*. The speech areas do not develop in both hemispheres. In right-handed individuals, they become fully developed only in the left hemisphere, and in left-handed persons, in the right hemisphere.

371. Association Areas.—In the frontal and parietal regions of the cerebrum are what are known as the *association areas*. These differ in some respects from other parts of the brain. Some of the differences are as follows: The association areas have no projection fibers—*i. e.*, those connecting the cortex with the medulla and cord—but they have an inconceivably large number and complex arrangement of association fibers—*i. e.*, those connecting different points of the cortex. The association areas are, however, connected by association fibers with motor and sensory centers which are supplied with projection fibers. The association areas in man are much larger than those in even the higher apes whose brains more nearly resemble the human type than do those of other animals. The association areas develop later in life than the other parts of the brain.

372. It is thought that it is the association areas which control the higher and more complex mental activities, that they are the seat of reasoning, judgment, will, voluntary inhibition, of imagination, of emotions, as love, hate, sympathy. Also, it is in the association areas that the connec-

tions, termed *memories* of things read, heard, seen, and studied are made.

373. Little is known of the manner in which the association areas perform their function. Dr. Howell says:

"*In the association areas our memory records of past experience and their connections are laid down in some, as yet unknown, material change in the network of nerve cells and fibers.*"[1]

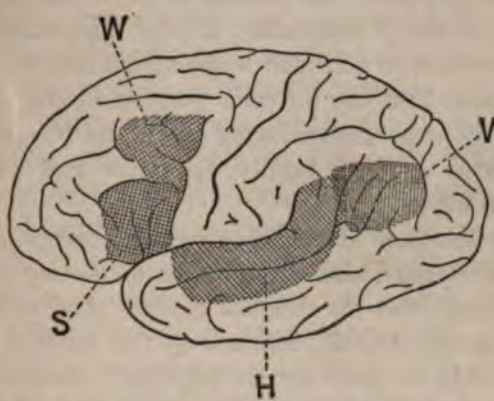

FIG. 74.—Lateral view of a human hemisphere; cortical area *V*, damage to which produces "mind-blindness" (word-blindness); cortical area *H*, damage to which produces "mind-deafness" (word-deafness); cortical area *S*, damage to which causes the loss of audible speech; cortical area *W*, damage to which abolishes the power of writing. (Howell.)

374. After definite centers had been localized

[1] *Text-Book of Physiology*, page 220. Howell, Saunders & Co.

for many of the motor sensory and secretory functions of the body, it was thought that there must be also centers for the different functions performed by the association areas; but, at present, the common opinion of neurologists is that there are no centers for the different higher mental faculties, but that the association mechanism as a whole is concerned in these.

375. It is thought probable, however, that the areas in the posterior portion of the cerebrum may be particularly concerned in the organization of the experiences founded upon visual and auditory sensations and the anterior portion in the organization of experiences based upon the internal associations such as bodily appetites and desires. Howell says:

"*In this part of the brain possibly arises the conception of individuality, the idea of the self as distinguished from the external world. And in alterations or defective development of this portion of the brain may lie possibly the physical explanation of mental and moral degeneracy.*"[1] This latter view developed from the fact that, in autopsies performed on those who in life had always been mentally deficient, the frontal association area was found undeveloped, and in autopsies on those who suffered from certain forms of insanity the cortex in this area was frequently found to be more or less atrophied.

376. As previously stated, at birth the associa-

[1] *Text-Book of Physiology*, page 222. Howell, Saunders & Co.

tion areas are not well developed. They, more than any other part of the brain, then, contain but the potential elements for their future capacities and these, as in the case of the simpler capacities of the nervous system, are determined largely by the nature of the impulses received and by the way in which the individual forms the habit of reacting to these impulses.

377. The whole environment of a child, all that it sees and hears, provide the impulses that help form the nervous connections which determine its character. As age advances, the brain becomes less plastic, the individual less adaptable to new surroundings, and habits and ideas are harder to change. One of the most influential causes of this is that the ways of response to stimuli have been established. The age at which this occurs varies very greatly in different individuals. Common causes of early mental inflexibility are (1) a monotonous life, which affords little occasion for variety in the ways of responding to stimuli; (2) lack of training and use of the higher mental capacities by study, reasoning, etc.; (3) ill-health. For, to function properly, the brain, like other parts of the body, needs sufficient exercise and healthy tissue.

378. Though the association areas are developed by the impressions and reactions to which they are subjected, the character and capacities of people, even when brought up in the same manner and surroundings are never exactly alike,

for the potential capacities of the brain differ in different individuals. The genius, for example, has some inherent mental quality at birth, but not, it is now considered, a center for his special talent. Neither is it now thought that a brain endowed with the latent capacity for any one art or science has necessarily the potentiality for greatness in other qualities, nor that the study of one art or science helps with that of another unless the two are of similar character or correlate in some way.

The Mesencephalon or Mid-Brain*

379. *Location and Structure.*—The mesencephalon, often called the isthmus of the brain, is the narrow neck which connects the cerebrum with the structures below. Its ventral part is shaped like two pillars which converge toward the pons. It is called the *crura cerebri.* On the dorsal surface are four rounded prominences called the *corpora quadrigemina.* The mid-brain is hollow, the aqueduct of Sylvius traversing its length.

The Cerebellum*

380. *Location, Size, and Divisions.*—The cerebellum is the great solid mass of nervous tissue lying back of, but on the same plane as, the pons Varolii. It is oblong in shape and measures about three and a half to four inches transversely and two to two and a half from before backward. It is divided by fissures into three lobes, one medial,

known as the *vermis* or *worm*, and two lateral, called the *cerebellar hemispheres.*

381. *Connections.*—The cerebellum is connected with the rest of the brain by six bands of white nerve-fibers, three on either side, called the *superior* or *anterior*, *middle*, and *inferior* or *posterior peduncles.* The nerve-fibers of the peduncles, some of which are continuous with those of other parts of the brain and some with those of the spinal cord, terminate in fine networks of fibrils about cells in the gray matter, and an impulse that comes into the cerebellum from one of the higher centers in the cerebrum may be subdivided into a great number of currents that, passing to and down the cord, and thence to the periphery, will produce co-ordinate action in a whole group or groups of muscles. The cerebellum has no cavity.

382. Arrangement of Gray and White Matter.—The bulk of the gray matter of the cerebellum, like that of the cerebrum, is on the exterior, and the white in the interior. Also like that of the cerebrum, the gray matter dips into the white matter in order that a larger amount may be contained in a given space. Beside the gray matter on the surface there is a small mass near the center of the white matter called the *corpus dentatum.*[1]

383. Functions of the Cerebellum.—It is thought that co-ordination of ordinary movements

[1] From the Latin *corpus*—a body and *dentatus*—toothed, tooth-shaped body.

and maintenance of equilibrium are the principal, if not the only, functions of the cerebellum. The chief reason for this belief is that injury to, or disease of, this part of the brain does not seem to interfere with the intellect nor with the power of actual movement, but only with the power of co-ordinating muscular movements, especially those connected with locomotion and equilibrium, which results in a loss of ability to stand, walk, etc.

384. In reference to the reason for this loss of co-ordination Dr. Howell says[1]:

"*We may assume that the cerebellum exerts its co-ordinating influence by virtue of the definite nervous mechanisms contained in it—that is, by nervous complexes which, on the afferent side, are connected with the peripheral sensory nerves to the vestibule of the ear,*[2] *the muscles, joints, etc., and on the efferent side are in direct or indirect relations with the motor areas of the brain as well as the motor centers in the cord. These mechanisms are inherited structures, but, like other nervous mechanisms, they are developed by use. The many muscular contractions made in our ordinary movements of equilibrium are learned by experience, and the effects of this training are felt mainly upon those cerebellar paths or mechanisms. We regard the speech center in the cerebrum as a collection of nervous mechanisms in which are stored or preserved the connections necessary to the motor presentation of thoughts, a memory for the spoken symbols of our concepts. It is possible that in the same way we may regard the cerebellum as a memory center of the muscular movements concerned in equilibrium.*"

[1] *Text-Book of Physiology*, page 237. Howell, Saunders, & Co.

[2] A portion of the inner ear is also concerned in maintaining equilibrium. (Described in paragraphs 987 and 992.)

The Pons Varolii[1]

385. LOCATION.—The pons Varolii* (bridge of Varolius) is situated below the crura cerebri above the medulla oblongata and between the two hemispheres of the cerebellum.

386. STRUCTURE.—The pons presents the appearance of a prominence composed of strands of white nerve-fibers some of which run transversely and some longitudinally. The transverse strands narrow towards either side and are continued into the cerebellum. Some of the longitudinal fibers are those motor fibers passing down from the motor centers in the cortex of the cerebrum to the cord where they are known as the pyramids. Others, which pass upward, are the sensory tracts and lead upward from the sensory nuclei in the upper part of the posterior columns of the spinal cord and lower part of the oblongata to the optic thalami, two small oval bodies which rest upon the cruri cerebri and contain nuclei that form important auxiliary centers for several of the body movements.

387.—ARRANGEMENT OF GRAY MATTER IN THE PONS.—The gray matter of the pons no longer forms a cortex, as in the cerebrum, nor a continuous column, as it does in the spinal cord, but it is cut up into small masses which are scattered among the interlacing fibers.

[1] Latin, a bridge. Varolius, name of the anatomist who discovered the pons.

388. The fifth, sixth, seventh, and eighth cranial nerves pass from the brain either through the pons or between the pons and medulla oblongata. See Fig. 71.

The Medulla Oblongata

389. LOCATION.—The medulla oblongata, known also as the *spinal bulb*, is situated under the mid-brain and pons and above the spinal cord. In fact, the medulla is simply a widening out or expansion of the cord. The medulla rests in a groove in the lower part of the occipital bone, directly above the foramen magnum (paragraph 112) through which the spinal cord enters the cranial cavity. The medulla is directed (from above) obliquely downward and backward.

390. FORM.—In shape, the medulla resembles a truncated cone with its base upward and attached to the pons.

391. STRUCTURE.—Like other parts of the brain, the medulla consists of masses of gray matter and bundles of nerve-fibers. Some of the fibers are on the exterior and some in the interior. The anterior surface of the medulla and the lower part of the posterior are marked by a deep fissure, but the posterior fissure is soon replaced by the fourth ventricle which is formed by the expansion of the central canal of the spinal cord. The posterior surface of the medulla is largely occupied by the nuclei of origin of the cranial

nerves, from the sixth to the twelfth inclusive. Distributed throughout the substance of the medulla are masses of gray matter which constitute the automatic centers for the heart and respiration, vaso-motor centers and many others that govern important functions of the body. Also there are two convoluted masses of gray matter, lying one on each side of the middle line, known as the *olivary bodies*. Their function is unknown, but it is thought that they may help us to maintain the upright position. The nerve-fibers composing the sensory tracts—those passing from the spinal cord to the brain—change their position considerably on entering the brain, some passing to the sides while others cling to the middle line. The motor fibers—those going from the brain to the cord—now come to lie in two composite groups, one on each side of the middle line, on the anterior surface. They are known as the pyramids.

392. Decussation of the Pyramids.—Toward the lower end of the medulla, some of the fibers of each pyramid change their course, passing over to the opposite side to occupy a position in the lateral columns of the cord (page 190). This crossing of fibers is known as the decussation of the pyramids. This decussation accounts for the fact that injury involving the motor cortex of one side of the cerebrum causes a paralysis on the opposite side of the body.

393. Cavities of the Oblongata.—Like the other parts of the brain, excepting the cerebellum,

which, it will be remembered, is solid, the medulla oblongata is hollow; the cavities which make it so are the upper end of the central canal of the spine and the expansion of the latter, which is known as the fourth ventricle (see Fig. 69).

394. FUNCTIONS OF THE MEDULLA OBLONGATA.—The functions of the oblongata are those of conduction, reflex action, automatism.

395. CONDUCTION.—As a conductor of nerve impulse the oblongata has a wider extent of function than any other part of the nervous system, since all impressions passing between the brain and spinal cord must be transmitted through it.

396. REFLEX AND AUTOMATIC ACTION.—The most vital reflex and automatic centers of the body are situated in the oblongata, *e. g.*, the respiratory center, the accelerator centers for the heart, the vaso-motor centers, the center controlling the impulses which enable the muscles of the palate, pharynx, and esophagus to produce the successive co-ordinate movements necessary to the act of swallowing, and many others. So important are the functions of the medulla oblongata that injury to it is likely to result in instant death.

397. UNITY OF THE NERVOUS SYSTEM.—Though the manner in which the nerve-fibers and the gray matter are arranged in the brain makes it convenient to study certain portions as though they were separate parts, it is to be remembered that all parts of the brain and also the spinal cord and sympathetic ganglia are intimately connected with one another; for, as already stated, nerve-

fibers extend between the outer surface and organs of the body and the nerve-centers and from certain nerve-centers to others. Another point to be appreciated is that centers in several parts of the brain and cord must be stimulated and transmit the stimuli to motor nerves that will carry impulses to the muscles in order that we may accomplish such simple actions as walking, maintaining balance, and the like. Probably it is only very simple reflexes that involve but one group of sensory and motor centers; therefore, learning to do anything involves the establishment of proper communication between various nerve-centers.

398. The Membranes Covering the Brain. —The brain and spinal cord are enveloped in three membranes or meninges,[1] the outer one of which is known as the *dura mater*, the middle as the arachnoid, and the innermost one as the *pia mater*.

399. The Dura Mater.*[2]—The dura is a strong tough, inelastic fibrous membrane containing a great number of blood-vessels. It is arranged in two layers which are attached to each other except in a few parts. The external surface is adherent to the bones of the skull, thus forming its internal periosteum. In some places the inner layer of dura separates from the outer and projects inward. These projections form supports for the lobes of the brain, nerves, and blood-vessels, and in some places form sinuses for the veins that return the blood from the brain; also it forms sheaths for the nerves as they pass from the skull.

[1] Meninges. From the Greek *meninggos*—a membrane.

[2] Dura mater. Latin, hard mother.

400. THE PIA.*—The pia, or pia mater,[1] consists of blood-vessels held together by areolar tissue. It is the nourishing tunic of the brain and lies close to its surface, dipping into and extending to the bottom of every fissure. It covers the roots of the nerves and becomes merged with their connective-tissue sheath, and branches of its arteries extend into the substance of the brain.

401. THE ARACHNOID.*[2]—The arachnoid is a thin, delicate membrane situated between the dura and the pia, but nearer the former, as, except in the case of the longitudinal fissure, it does not follow the pia into the fissures. It is connected with the dura by means of small, oblique bundles of fibers. It resembles serous membranes in its nature and function—*i. e.*, it secretes a serous fluid which lubricates the other membranes and so prevents friction. Like the serous membrane lining the ventricles, the arachnoid when inflamed—meningitis—secretes an excessive amount of fluid.

402. THE CEREBRO-SPINAL FLUID.—The ventricles of the brain, the central canal of the spinal cord, and the space between the arachnoid and the pia are filled with a clear fluid called the *cerebro-spinal fluid*. This acts as a water bed for the brain and cord and minimizes the danger of ill effects from blows on the head and spinal column. In meningitis, the quantity of fluid becomes increased, and the symptoms occurring during the disease are partly due to its pressure upon the brain.

[1] Latin, tender mother.

[2] From the Greek *arachne*—a spider's web, and *eidos*—form.

CHAPTER IX

THE NERVOUS SYSTEM—*Continued*

THE SPINAL CORD. THE SYMPATHETIC SYSTEM. THE NERVES

The Spinal Cord: Location, Membranes, Structure, Function. Different Sets of Nerves. Number, Origin, Nature, and Names of the Cranial and of the Spinal Nerves. Roots and Ganglia of Spinal Nerves. Distribution of the Peripheral Branches of the Spinal Nerves. The Sciatic Nerve. The Sympathetic System: Constituents, Nature of Ganglia, Distribution of Nerves. Connections between the Spinal and Cerebro-spinal Systems. Function. Influence of Cerebro-spinal System on the Sympathetic, Vaso-motor Centers and Nerves.

The Spinal Cord

403. LOCATION.—The spinal cord is the terminal portion of the cerebro-spinal axis. It is contained within the canal formed by the union of the vertebra and the intervertebral disks of cartilage, and extends from the foramen magnum[1] to the body of the second lumbar vertebra, where it terminates in a fine non-nervous strand called the *filum terminale*. The collected nerves arising

[1] Described in paragraph 112.

from the lower end of the spinal cord are called the *cauda equina.*[1]

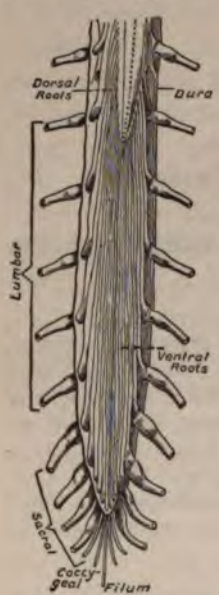

FIG. 75.—Lower end of the spinal cord and the cauda equina, dorsal aspect. The dorsal roots of the right side have been removed.

404. DIFFERENCES BETWEEN THE MEMBRANES OF THE CORD AND THOSE OF THE BRAIN.—Like the brain, the cord is surrounded by the three membranes known as the *dura mater*, *pia mater*, and *arachnoid*. Though these membranes are direct continuations of the ones covering the brain they differ slightly from the latter in their structure; thus, the dura does not form the periosteum of the vertebral bones, as it does of the skull, but it hangs like a long tube within the canal, and this prevents it interfering with movement between the vertebra.

405. The pia of the cord is more fibrous and less vascular than is that of the brain, and it has on each side a long band of connective tissue, on the outer edge of which are sharp projections which extend and are attached to the dura between the places where the spinal nerves perforate that membrane.

[1] Latin, a horse's tail.

There are also some slight points of difference in the arachnoid, but these need not be mentioned here.

406. Structure of the Cord.—The substance of the cord is made up of gray and white nervous matter supported by neuroglia. The gray matter which, it will be remembered, consists of the cell-bodies with their dendrites, the beginning of the axis cylinder processes, and collaterals, is massed together in something the shape of the letter H, around the canal which runs through the center of the cord. The white matter, which consists of medullated nerve-fibers, is grouped in bundles known as tracts or columns, on the outside of the gray matter. Some of these tracts have their origin in the gray matter of the cord, and their terminations in the gray matter of the brain. These are termed *ascending* or *sensory tracts* because they carry impulses to the brain. Others arise from cell-bodies in the gray matter of the brain and terminate in arborizations around cells in the gray matter of the cord; these are termed *descending* or *motor tracts* and they convey impulses downwards. The names of the more important tracts are:

Descending	*Direct pyramidal tracts* *Crossed pyramidal tracts*
Ascending	*Columns of Goll* *Columns of Burdach* *Direct cerebellar tracts*

In addition to these long tracts there are columns which consist of bundles of fibers, no one of which is continuous throughout the cord. These columns, which are known as the *lateral columns*, serve to connect centers in different

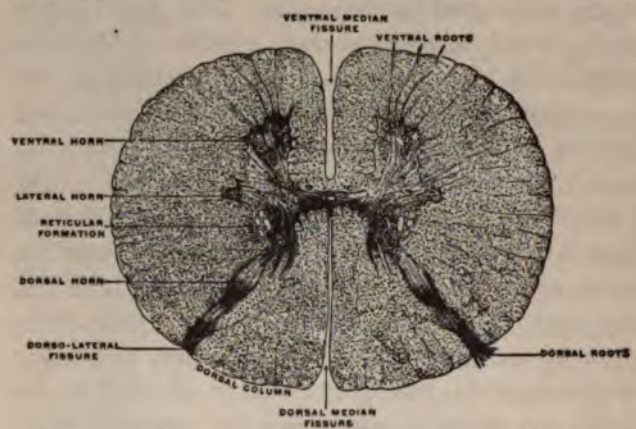

FIG. 76.—Transverse section of the spinal cord at the middle of the thoracic region. The neuroglia septum has been removed from between the dorsal columns. (Gerrish.)

parts of the cord. They contain both sensory and motor nerve-fibers.

407. NAMES OF DIFFERENT PARTS OF GRAY MATTER.—The transverse bar uniting the two lateral masses of gray matter is spoken of as the *gray commissure;* the points of the side masses are named the *horns*, the two in front being called the *anterior horns* and the two in the back the *posterior*.

408. FISSURES AND CANAL OF THE CORD.—

The substance of the cord is almost completely divided into two lateral halves by two fissures, one in front—the *ventral* or *anterior fissure*, and one in the back—the *dorsal* or *posterior fissure*, and by the *central canal* which extends through the entire length of the center of the cord.

409. FUNCTION OF THE CORD.—Within the gray matter of the cord, the impulses entering from the sensory peripheral or visceral nerves are transmitted to motor fibers going to the periphery, or to sensory cell-bodies from which fibers pass to the brain—the ascending columns—or to both; and impulses coming from the brain are transmitted to motor fibers passing outward from the cord. Thus the spinal cord serves as a center for the transmission of impulses and as a conduction path to and from the brain; also it, with the medulla oblongata, is the center for reflex actions.

The Nerves

410. There may be said to be four sets of nerves in the human body: (1) The cranial nerves which pass to and from the brain through openings in or between the bones forming the base of the skull and do not become a part of the spinal cord; (2) the cerebro-spinal nerve-fibers extending between the brain and the cord and forming the tracts or columns (white matter) of the cord; (3) the spinal nerves and their peripheral branches, those connecting the spinal cord

with the periphery and with the sympathetic system; (4) the nerves of the sympathetic system.

The Cranial Nerves

411. NUMBER AND ORIGIN.—In man there are twelve pairs of cranial nerves. They appear to arise, in a double series, from the under surface of the anterior surface of the cerebrum and the medulla oblongata (see Fig. 71) and this is called their *superficial origin;* but they can be traced back to various masses of gray matter in the higher parts of the brain. These parts are called their *deep* or *real origin.*

412. NATURE.—Some of the cranial nerves are purely sensory; others are entirely motor, and some are mixed, *i. e.*, both sensory and motor. Most of the cranial nerves arise from several roots, *i. e.*, groups of cell-bodies, and consist of many bundles of nerve-fibers which in some cases, after the nerve emerges from the cranium, become split up and branch to various parts of the body.

413. NAMES.—The cranial nerves were named by numbers corresponding to the order of their superficial origin in the brain, beginning at the top, and also by names descriptive of their nature, function, or distribution. Their names, distribution, and function can be seen in the following table. In the section on the right is a doggerel used by students of anatomy as a help to connect the numerical and ordinary name of the nerves.

Table of the Cranial Nerves

Names.	Distribution.	Function.	Doggerel.
1. Olfactory.[1]	Upper third of nasal cavity.	S.[2] Smell.	On.
2. Optic.[3]	Retina (Inner membrane of the eye).	S.[2] Sight.	old.
3. Oculomotor.	Muscles of eyeball, except external rectus and superior oblique.	M.[4]	Olympus.
4. Pathetic or Trochlear.	Superior oblique of eyeball.	M.[4]	piney.
5. Trifacial or Trigeminal.	Sensory part of face and tongue, motor, to muscles of mastication.	S. and M.[5]	tops.
6. Abducent.	External rectus of eyeball.	M.[4]	a.
7. Facial.	Sensory part to tongue, motor to those muscles of the face concerned in expression.	S. and M.[5]	Finn.
8. Auditory.	Membranous labyrinth of ear (described in paragraph 984).	S. Hearing and equilibrium.	and.
9. Glossopharyngeal.[6]	Pharynx (see paragraph 602) and back part of tongue.	S. Taste. A few motor fibers.	German.
10. Pneumogastric[7] or Vagus.[8] (pl. vagi).	Sensory to external ear. Motor and sensory to pharynx, trachea, lungs, esophagus, stomach, heart, liver.	S. and M.	picked.
11. Spinal accessory.	A portion of the spinal accessory joins and is distributed with the vagus. The other portion supplies the sternomastoid and the trapezius muscles.	M.	some.
12. Hypoglossal.	Muscles of the tongue.	M.	hops.

[1] From the Latin *olfacio*—to smell. [2] Sensory.
[3] From the Greek *optikos*—belonging to the sight.
[4] Motor. [5] Sensory and Motor.
[6] From the Greek *glossa*—the tongue and *pharynggos*—the pharynx.
[7] From the Greek *pneumon*—the lung and *gaster*—the belly.
[8] Latin wandering. The nerve is so called from its wandering course.

414. Cerebro-Spinal Nerves.—The cerebro-spinal nerves are those which form the white matter of the cord and, except for the cranial nerves, the white matter of the brain. Their arrangement has been already discussed.

Spinal Nerves

415. Number and Names.—In man there are thirty-one pairs of spinal nerves. They were named for the regions of the vertebral column where they emerge; thus there are:

8 Cervical—region of the neck
12 Thoracic—region of the chest
5 Lumbar—region of the loins
5 Sacral
1 Coccygeal—terminal portion of the spinal column.

416. Origin.—The spinal nerves, with the exception of the first cervical, spring from both sides of the spinal cord and emerge, with the exception of the first cervical and the coccygeal, through the intervertebral foramina—openings. The first cervical nerve arises from the medulla oblongata and leaves the neural canal between the occipital bone and the atlas; the coccygeal passes from the lower end of the canal.

417. Nature of Spinal Nerves.—The spinal nerves consist almost entirely of medullated nerve-fibers; they contain both motor and sensory fibers, and are therefore called mixed nerves.

418. Roots of Spinal Nerves.—Each nerve

is attached to the cord by two roots. One, called the *anterior root*, springs from the ventral horn of gray matter in the cord. It consists of bundles of motor fibers. The other, known as the *posterior root*, arises from the dorsal horn. It is composed of sensory fibers, and it differs somewhat in appearance from the motor root, the principal difference being the presence of a ganglion (see Fig. 77). The two roots join, *i. e.*, they come together, and the fibers composing them are held in contact by an investment of connective tissue —immediately beyond the ganglion, that is, just as they are passing through the intervertebral foramen.

FIG. 77.—Formation of a spinal nerve.

419. SPINAL GANGLIA.—The ganglia on the sensory or posterior roots of the spinal nerves consist of small ovoid masses of gray matter. They are placed in the intervertebral foramina.[1] The cell-bodies of these ganglia are bipolar, and one pole of each cell passes into the spinal cord *via* the posterior root, and the other passes outward. The processes passing outward are the fibers which, uniting with the fibers from the anterior root, form a *spinal nerve.*

420. DISTRIBUTION OF THE PERIPHERAL

[1] Openings between the vertebræ, through which the roots pass.

BRANCHES OF THE SPINAL NERVES.—Almost immediately after emerging from the vertebral column each spinal nerve divides into two main trunks known as the *anterior* and *posterior* divisions. Each division contains both sensory and motor fibers. The posterior divisions pass backward and give off branches which supply the muscles and skin of the back of the head, neck, and trunk. The branches of the anterior divisions supply the parts of the body in front of the spine and the extremities. Each anterior division gives off fibers to, and receives fibers from, the sympathetic system. In the cervical, lumbar, and sacral regions, the branches of this division form plexuses, previous to their distribution. These are known as the *cervical*, *lumbar*, and *sacral plexuses*. The nerves in passing to their destination in the peripheral muscles, skin, etc., usually follow the same pathways as the blood-vessels. The various natures of their endings were described in paragraph 323.

421. NAMES OF PERIPHERAL NERVES.—The Great Sciatic Nerve. The majority of the larger nerves bear the name either of the blood-vessels with which they are continuous or else of the locality which they supply. An exception to this are the two great sciatic nerves which pass down, one on either side of the body, near the center of each buttock and back of each thigh to the popliteal region.[1] Motor branches pass from

[1] Region back of the knee.

these nerves to all of the muscles of the legs and feet, and they receive sensory branches from nearly all parts of the skin of the lower extremities. This nerve is of particular interest to nurses, as it is sometimes the seat of a troublesome form of neuritis—inflammation of a nerve—known as *sciatica.*

The Sympathetic System

422. CONSTITUENTS.—The sympathetic system may be said to consist of: (1) Two chains of ganglia and fibers, variously known as the lateral or vertebral ganglia and the gangliated cord, which extends from the cranium to the pelvis along each side of the spinal column, within the thoracic and abdominal cavities, and from which branches are distributed both to other parts of the sympathetic system and to the cerebro-spinal system; (2) irregular groups of ganglia called collateral or prevertebral ganglia and plexuses of nerve-fibers which give off branches to the thoracic and abdominal viscera; (3) various ganglia known as the terminal ganglia, and plexuses in the substance of some of the viscera; (4) sympathetic nerve cells in the brain and spinal cord.

423. NUMBER OF LATERAL GANGLIA.—In the thorax the number of sympathetic lateral ganglia corresponds with the number of spinal nerves, but in the cervical and lumbar region some of the ganglia are fused together so that while there are thirty-one spinal nerves passing from each side of

the cord there are only twenty or twenty-three ganglionic masses.

424. Nature of and Connections between the Sympathetic Ganglia.—The ganglia lying on either side of the spinal column—the lateral ganglia—consist of small masses of gray matter linked to each other by bundles of nerve-fibers

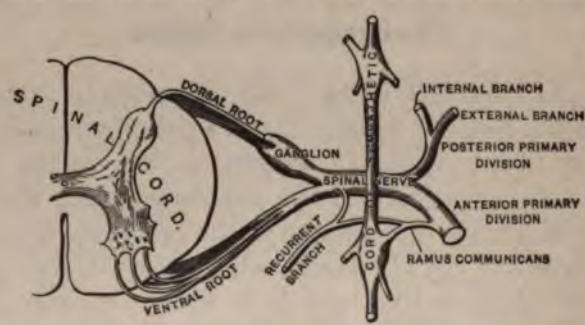

Fig. 78.—Plan of the constitution of a spinal nerve. (Gerrish.)

called the *ganglia cords* (see Fig. 78). They are connected to the spinal nerves by branches called the *rami communicantes* (these will be described in the next paragraph), and to the viscera, including the blood-vessels, by branches which reach their destination in several ways: (1) they pass directly to the viscera; (2) they join the collateral ganglia and plexuses; (3) they first converge to form three main trunks known as the *great splanchnic*[1] (*visceral nerve*), the *small splanchnic nerve*, and the *least splanchnic nerve*, and then

[1] From the Greek *splangchnon*—a bowel.

branch off and pass to different viscera; (4) they join the spinal nerves by way of the gray rami communicantes (see next paragraph) and in them reach the vessels, fascia, bones, etc., for which they were destined. The collateral or prevertebral ganglia consist of aggregations of nerves and ganglia which, as stated in paragraph 420, form plexuses that give off branches to the thoracic and abdominal viscera. The chief of these plexuses are: the *cardiac plexus*, situated above the heart and supplying it; the *solar plexus* lying in the abdomen behind the stomach and supplying most of the abdominal viscera and their vessels; and the *hypogastric*[1] *plexus*, which is placed in the center of the lower part of the abdomen and supplies the pelvic viscera. In many of the internal organs the nerve branches derived from the prevertebral plexuses form a secondary plexus called the *terminal plexus*, and from these plexuses branches pass in between the individual muscles of the organs and send off fine fibrils which terminate on the walls of the muscle cells.

425. Rami Communicantes.[2]—As stated in the preceding paragraph, the lateral ganglia of the sympathetic system are connected with the spinal nerves by branches called the *rami communicantes*. Usually two rami communicantes connect a sympathetic ganglia with a spinal nerve. The two rami differ from each other in color, one consisting of medullated and the other of non-

[1] Described in paragraph 702. [2] Communicating branches.

medullated fibers. The former is therefore called the *white ramus* and the latter the *gray ramus*. The white ramus consists of fibers which emerge from the spinal cord and pass to the sympathetic ganglion; the gray consists of axons of cells contained in the sympathetic ganglion which pass out and join the spinal nerve (see Fig. 78), and so reach the vessels, etc., which they are to supply. They then branch off and enter the substance of the organ.

426. Action of the Sympathetic System.—From the foregoing description, it can be appreciated that, with the exception of the muscles, nearly all the organs of the body are influenced by the sympathetic system. The nature of this influence varies, however, for the activity of some organs is increased and that of others inhibited by stimulus from this source. Thus, stimulus from the sympathetic system: (1) increases the rate of the heart action; (2) helps to maintain the tone of the muscle tissue of the majority of the arteries and arterioles and thus to regulate the caliber of the vessels (see paragraph 428); (3) may inhibit the action of the digestive organs, and causes: (4) the liver to give up some of its glycogen supply; (5) contraction of the internal genital organs; (6) relaxation of the bladder; (7) dilation of the pupil of the eye; (8) the secretion of sweat and adrenin; and (9) the contraction of small muscles in the skin, producing thereby the appearance known as goose-flesh.

427. AUTONOMIC SYSTEM.—Though the influence of the sympathetic system is most important to the functioning of the viscera, it is not, by any means, the only essential factor in their nerve control, for fibers received from parts of the central system are equally important. Portions of the central system supplying involuntary muscle together with the sympathetic system, have, lately, been classed as the *autonomic system.* About the most important part of the central portion of the autonomic system are the vagi centers and nerves, fibers from which go to the mucous membrane and some of the muscles of the pharynx, larynx, trachea, bronchi, esophagus, stomach, and intestines; and to the liver, lungs, heart, and large arteries. Some of its fibers are sensory, some motor, causing secretion and muscular contraction, and some—those going to the heart—are inhibitory.

428. THE VASO-MOTOR NERVES.—These nerves control the caliber of the blood-vessels and thus help to control many of the important processes of the body, such as the circulation of the blood, metabolism, heat regulation. There are two sets of vaso-motor nerves one being known as *vaso-constrictors* and the other as *vaso-dilators.* The vessels of the heart, lungs, and brain are not supplied with vaso-constrictor nerves.

429. LOCATION OF VASO-CONSTRICTOR CENTERS AND DISTRIBUTION OF VASO-CONSTRICTOR NERVES. —It has been found that the main vaso-constrictor

center is in the medulla oblongata and that the cell-bodies composing it give off neuraxons which descend to various levels in the cord where they terminate in cells contained in the anterior horns of gray matter. These cells form what are known as the *spinal vaso-motor centers*, and they give off axons which pass to cells in the sympathetic ganglia, whence fibers are continued to the blood-vessels, more especially those of the skin and of the abdominal viscera. Under normal conditions the vaso-constrictor centers in the cord do not work independently of those in the medulla oblongata, but when action of the latter has been lost by injury, vessel tone has been shortly established by the influence of the centers in the spinal cord and sympathetic ganglia. The center in the oblongata is in constant action, in consequence of which the arteries it supplies are kept in a condition of tone or slight contraction. This has been proven by experiments on animals in which the fibers that transmit impulses from this center have been cut, such experiments resulting in dilation of the blood-vessels. The ordinary normal degree of tonicity may be either increased or decreased by reflex stimulation of the center through the sensory nerves. Thus, there are certain afferent nerves which, when stimulated, cause reflexly an excitation of the vaso-constrictor center, and consequent constriction of the peripheral arteries. Other sensory nerves when stimulated cause a lessening of the tone of the vaso-constrictor center and

consequent dilation of the blood-vessels. Thus, dilation of the blood-vessels may take place as the result of depression or inhibition of the action of the vaso-constrictor centers as well as by stimulation of the vaso-dilator fibers.

430. Vaso-Dilator Center and Distribution of Nerves.—The vaso-dilator nerve-fibers arise, it is thought, from separate cells in the medulla oblongata, no definite general center having been found. The parts of the body the blood-vessels of which are supplied with these fibers seem to be the erectile tissue,[1] secretory glands,[2] the bucco-facial region, and the muscles. The vaso-dilator fibers seem to end in the muscular tissues of the walls of the arteries supplying those parts, and it is thought that they act, when stimulated, by inhibiting or depressing the usual tonic contraction of this tissue. The vaso-dilator fibers, unlike the vaso-constrictor fibers, are not in constant activity, but become active only in response to stimuli transmitted from sensory nerves. Examples of vaso-dilation are the flushing of the face known as blushing—the usual stimuli in such cases being of psychic origin, *e. g.*, embarrassment, anger, etc.,—and the congestion of the vessels in the salivary glands, the secretory glands of the stomach, etc., during mastication and digestion.

[1] Described in the chapter dealing with the organs of generation.

[2] Described in Chapter XVI.

CHAPTER X

MEMBRANES[1]

Nature. Classification. Function. Secretion. Serous Membranes: Structure, where Found. Synovial Membranes: Structure, Nature of Secretion, Classification, Nature and Location of Different Kinds of Membrane. Synovitis and Bursitis. Mucous Membranes, where Found, Structure, Nature of Secretion.

431. NATURE OF MEMBRANE.—The free surfaces of the body and its organs, both internal and external, are covered with membrane, *i. e.*, a thin,

FIG. 79.—A typical membrane in vertical section. (Gerrish.)

sheet-like expansion of tissue. In the widest sense of the meaning of the word *membrane* it can be, and often is, used for any thin, expanded sheet of tissue, as, for instance, the periosteum covering the bones, and the thin layer of cells beneath the epithelium of certain surfaces, commonly known as *basement membrane;* but, in its more restricted sense, the word is applied to sheets of tissue

[1] From the Latin *membrana*—a skin.

covering parts or lining cavities which have a free unattached surface.

432. Classification of Membranes.—There are four different classes of membranes answering the foregoing description. They are called:

1. Serous membranes
2. Synovial membranes
3. Mucous membranes
4. Cutaneous membrane

433. Function of Membranes.—With the exception of the cutaneous membrane or, as it is usually called, the skin, which has many functions, the chief purpose of these membranes is the protection of the parts they cover. Some of the serous membranes also serve to connect and support the organs they invest, as, for instance, the folds of peritoneum[1] known as the mesentery[2] and the omentum,[2] and some of the mucous membranes, which are very vascular,[3] afford nutrient[3] for non-vascular parts which they cover.

434. Method of Protection.—These membranes afford protection in two ways: (1) by acting as a covering; (2) by secreting a lubricating fluid which keeps their surfaces moist and thus prevents friction between the contiguous organs of which the membranes form the covering. Also, in the case of mucous membrane, the secretion is

[1] The membrane lining the abdomen and covering its organs.

[2] Described in paragraph 703.

[3] Having a large number of blood-vessels. The blood is the conveyer of nutrient to the tissues.

somewhat thick and viscid, and thus prevents injury of the surface by substances entering the cavities and passages which it lines.

435. SECRETION.—By secretion is meant the taking, by secretory cells, of certain substances from the blood and changing them so that they are adapted to the purpose for which they are required. Also, the word is used to designate the substances so prepared. The secretions of the serous, synovial, and mucous membranes are simple in composition and, unlike the secretions to be discussed later in connection with the secretory glands, there is not much change made in the substance extracted from the blood.

Serous Membranes

436. STRUCTURE.—Serous membranes are thin, transparent, and somewhat elastic. They consist of two layers of tissue (1) the corium,[1] (2) the epithelium. The corium is a thin layer of tissue substance constructed of white and yellow fibrous and lymphoid tissues, and containing blood and lymph vessels and nerves. It is held to the underlying parts by areolar tissue, which in such locations is often called subserous tissue. The epithelium which forms the free surface of the membrane consists of closely fitted endothelial[2] cells. These cells secrete a thin serous[3] fluid which

[1] Latin *corium*—leather.

[2] From the Greek *endon*—within and *thele*—a nipple.

[3] This fluid resembles the serum of the blood, hence its name and that of the membrane.

keeps the membrane moist. Normally this fluid is present in very small amounts, for just as fast as it is secreted it is withdrawn by the lymphatics in the corium, but in certain diseased conditions affecting the membrane, equilibrium between the rate of secretion and absorption is disturbed and there is an accumulation of fluid in the part.

437. WHERE FOUND.—(1) Serous membrane lines the cavities and passages of the body which do not communicate with its exterior. These are: the thoracic and abdominal cavities, the cavity of the heart, of the blood and lymph vessels, of the brain and spinal cord, of the inner ears, and a small cavity at the back of each eyeball. (2) Serous membrane covers the lungs, the heart, the abdominal viscera, and the upper surface of some of the pelvic viscera.

438. SEROUS MEMBRANES PROPER.—The serous membranes covering the lungs and lining the thoracic cavity, the membrane covering the heart and that lining the abdominal cavity and investing and supporting its organs, differ in some respects from the membrane lining the other cavities, and they are often termed *serous membranes proper*. They will be further described in connection with the organs with which they are respectively related.

Synovial[1] Membranes

439. STRUCTURE AND SECRETION.—Synovial

[1] From the Greek *syn*—with and the Latin *ovum*—an egg.

membrane is composed of fibrous tissue that has on its free surface an imperfect covering of irregularly shaped cells which secrete a glairy, viscid fluid resembling the white of egg, and is therefore called synovial fluid.

440. CLASSIFICATION.—Synovial membranes are divided into three groups, viz.:

Articular synovial membranes
Bursal synovial membranes
Vaginal synovial membranes

441. ARTICULAR SYNOVIAL MEMBRANES.—These are found in articulations of the skeleton where two bones run upon each other when moving. It will be remembered that in the description of the joints it was said that the articular surfaces of such joints are covered with smooth hyaline cartilage and held together with strong ligaments that are lined with a synovial membrane, which turns inward and is connected with the cartilage, thus forming with the cartilage a closed sac between the two bones.

442. BURSAL SYNOVIAL MEMBRANES.—A synovial bursa is a small sac of fibrous tissue lined with synovial membrane and placed between parts which move upon each other, as two muscles, two tendons, a muscle or tendon and a bone, the skin and a bone. The sac is connected with the surrounding parts by areolar tissue, and the two surfaces facing each other are kept moist with synovial fluid, and friction thus prevented. Some

of the larger bursa are found over the patella, the olecranon, the malleoli, between the glutei muscles, and on the surface of the great trochanters.

443. VAGINAL SYNOVIAL MEMBRANES.—These are also called *synovial sheaths*. They are found in parts where the tendons or muscles run over bones, as do those of the flexor and extensor muscle of the fingers and toes. In these cases the bone is grooved and the membrane is in the form of a tube, and is attached at its outer under surface to the bone, and encloses the tendon in its cavity. The secreting surface forms the inside of the tube, and thus friction is prevented in the movements of the tendon.

444. SYNOVITIS AND BURSITIS.—As in the case of the serous membranes, the synovial normally secretes only a small amount of fluid, and that is constantly being absorbed; but inflammatory conditions, which occur most frequently as the result of injury, are likely to cause disturbance between the rate of secretion and absorption, and result, as in other inflammations, in an accumulation of fluid and consequent distension of the tissues and pain. This condition is known as *synovitis*, or, if a bursa is affected, as *bursitis;* the suffix *itis* meaning *inflammation.*

Mucous Membranes

445. WHERE FOUND.—Mucous membranes line the cavities and passages which communicate

with the exterior of the body. There are two separate sets of mucous membranes, each of which lines a continued series of organs. They are called the *gastro-pulmonary* and the *genito-urinary*. The

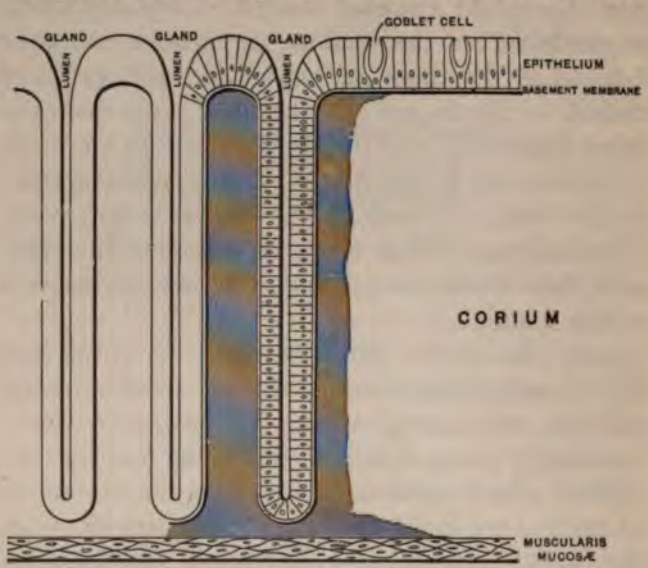

FIG. 80.—Diagram of mucous membrane in vertical section. (Gerrish.)

former, as the name denotes, lines the alimentary and respiratory tracts. The alimentary portion begins at the lips and is continued over the mouth, the middle and lowest part of the pharynx, the esophagus, stomach, small and large intestine, and at the orifice of the rectum it becomes continuous with the skin. In its course it sends offsets to the ducts of the salivary glands, the pancreas, the

liver, the gall-bladder, and the vermiform appendix. The respiratory portion begins in the nostrils and passes through the upper pharynx, the larynx, trachea, bronchi, bronchial tubes, and ends in the air vesicles of the lungs. The *genito-urinary mucous* membrane, as the name implies, lines the genital and urinary tracts. In both sexes the urinary mucous membranes line the urethra, bladder, ureters, and end at the papillæ of the kidneys. In the female that lining the genital tract begins at the vulva and is continued through the vagina, uterus, and two Fallopian tubes at the free ex-

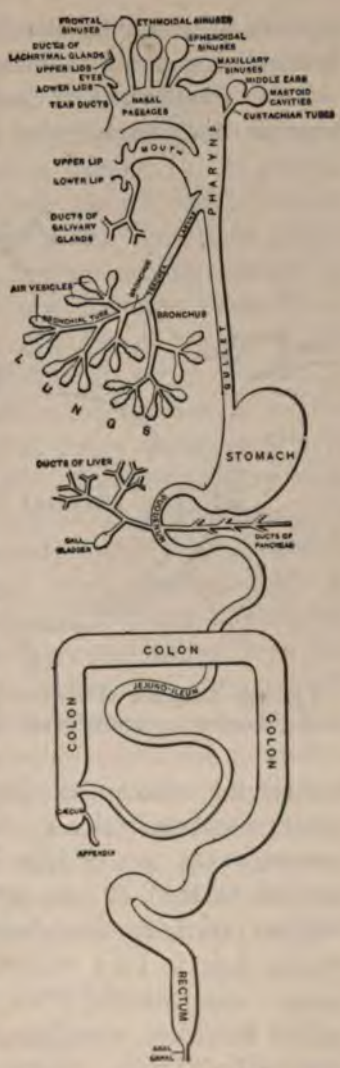

FIG. 81.—Diagram of the gastro-pulmonary mucous membrane, showing the continuity of all its parts. (Gerrish.)

tremity of which it blends with the serous membrane lining the abdominal cavity.

446. STRUCTURE.—Usually the foundation of mucous membrane—the part attached to the

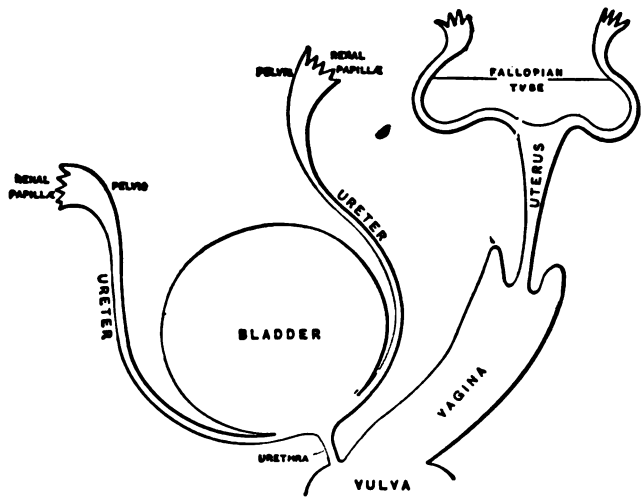

FIG. 82.—Diagram of female genito-urinary mucous membrane, showing continuity of all its parts. (Gerrish.)

underlying tissues—consists of a thin layer of plain muscular tissue, termed the *muscularis mucosa*. On top of this is the corium which is similar to that of the serous membrane, but is thicker, contains less elastic and more lymphoid tissue, and is very vascular. The corium is in most cases covered with a single layer of cells called basement membrane, and covering this are the epithelial cells. Mucous membranes, however,

vary considerably in their structure and the epithelium is the only element in the membrane that is never lacking. Other variations in mucous membranes are: (1) it is much thicker in some parts of the body than in others; (2) in certain locations it contains minute glands,[1] or its surface is covered with papillæ,[2] villi,[2] hairs,[3] or cilia[4]; (3) it is attached to the underlying tissues in different ways; for instance, in parts where there is no distention, as the interior of the nose, the membrane is attached directly to the bone; in other parts it is held to the under surface by areolar tissue, and the amount of tissue varies greatly in different parts of the body, there being very little in some locations and a great deal in others. In the stomach, for example, which is distended when full and collapsed when empty, there is such a large amount of areolar tissue holding the membrane to the elastic muscular wall of the organ that when the latter is empty and consequently collapsed, the mucous membrane is thrown into folds. This arrangement prevents the numerous small glands contained in the gastric[5] membrane becoming injured, as they would be if the membrane were stretched when the stomach became distended, as would happen if the membrane were elastic like the serous membrane, and applied

[1] Examples, the stomach and intestines.
[2] Examples, the intestines.
[3] Example, entrance to nasal cavities.
[4] Examples, the larynx, bronchi.
[5] Stomach.

tightly to the walls of the organ. The nature of the special forms of mucous membrane will be further described in connection with the organs which they line.

447. SECRETION OF THE MUCOUS[1] MEMBRANE. —The secretion of the mucous membrane is called mucus. It is thicker and more viscid than the secretions of the other two membranes; this is necessary because the mucous membrane is more exposed to irritating substances than the others.

[1] Latin *mucus*—the fluid within the nose.

CHAPTER XI

THE CIRCULATING FLUIDS OF THE VASCULAR SYSTEM

Divisions of the Vascular System. The Blood: Functions, Quantity, Characteristics, Color, Composition. Nature, Function, etc., of Corpuscles, Blood-plates, Plasma, Gases, Internal Secretion, and Antibodies Contained in the Blood. Clotting of Blood. Lymph: Nature, Derivation, and Function.

448. DIVISIONS OF THE VASCULAR SYSTEM.—The vascular system of the body is classed under two headings:

(1) The blood-vascular system
(2) The lymph-vascular system

The former consists of the heart, arteries, capillaries, and veins; the latter of the lymph spaces, the lymphatic vessels including the lacteals and ducts, and the lymphatic nodes or glands.

Before taking up the study of the organs of these systems we will consider the nature of the fluids for the conveyance of which the organs are required; the fluids being the essential feature and the organs only of use inasmuch as they serve to convey the fluids to and from the tissues.

The Blood

449. FUNCTIONS.—The blood serves several purposes in the body: (1) It carries to the tissues: (*a*) the material, including water, which they require for their growth and repair—this it gets from the alimentary canal; (*b*) oxygen—this the blood absorbs from the air while passing through the lungs—oxygen is necessary for the process of oxidation which must go on within the tissues in order to provide the heat and energy necessary to maintain the body mechanism at work; (*c*) certain glandular secretions which are necessary to promote oxidation and other important metabolic processes.

(2) The blood takes away from the tissues the waste products of the materials which have been broken down by oxidation and are not only of no use to the body but poisonous, and must therefore be eliminated by the kidneys, lungs, and skin, whither the blood carries them.

(3) The blood distributes and equalizes the heat produced in the tissues by oxidation.

(4) The blood contains certain constituents which aid in protecting the body from bacteria and other foreign substances.

450. QUANTITY.—The quantity of blood in the human body is generally estimated at from $\frac{1}{12}$ to $\frac{1}{14}$ of the total body weight.

451. CHARACTERISTICS.—Blood is a red, viscid, heavy, opaque liquid with a normal specific

gravity of between 1.041 to 1.067, of an approximately neutral reaction and a normal temperature of about 100°F.

452. Color.—The color of the blood is due to the hemoglobin which it contains in its red corpuscles or erythrocytes. The shade is variable and depends upon the amount of oxygen contained in the corpuscles. The blood in the arteries and pulmonary veins has the largest supply of oxygen and is of a bright scarlet hue. That in the veins, other than the pulmonary, has lost much of its oxygen and is therefore of a darker shade with a purplish tinge.

453. Composition of Blood.—Blood consists of:

(1) Water

(2) Solids
- Corpuscles
  - Red
  - White
  - Blood-plates
- Proteins such as:
  - Fibrinogen
  - Albumin
  - Globulin
  - Nucleo-proteins
- Fatty substances
- Sugar
- Inorganic salts
- Extractives which represent waste products such as:
  - Urea
  - Creatin
  - Lactic and other acids

(3) Gases
- Oxygen
- Carbon dioxide
- Nitrogen

(4) Enzymes

(5) Immune bodies such as: { Opsonins; Antitoxins; Antibacterial substances }

454. THE PLASMA.—The fluid portion of the blood is known as the plasma. So long as the blood is circulating in the blood-vessels, the solids and gases are held in suspension in the plasma, but if the blood escapes from the vessels, as in hemorrhage, the greater part of the solids will, under favorable circumstances, become formed into a firm mass which is known as a clot. Clotting of the blood will be further described in paragraph 483.

455. WHAT THE SOLID SUBSTANCES IN THE BLOOD REPRESENT.—The solids of the blood, with the exception of the corpuscles and, perhaps, the fibrinogen, represent: (1) the nutritive substances that are being carried from the alimentary canal to the tissues, and (2) the waste matter that is being carried away from the tissues.

456. RED CORPUSCLES OR ERYTHROCYTES.[1]—Chemical Composition. The red blood-corpuscles consist of:

Water
Hemoglobin
Protein substance
Fats { Cholesterin; Lecithin }
Inorganic salts

Oxygen, which is in loose combination with the hemoglobin.

[1] From the Greek *erythros*—red, and *kytos*—a hollow vessel.

457. STRUCTURE.—The red corpuscles[1] are flat, circular, biconcave disks. They consist of a colorless, transparent, extensible, spongy framework infiltrated in all parts by a red coloring matter termed *hemoglobin*, which contains a small amount of iron. Those in the blood have no nuclei.

458. PURPOSE.—By virtue of their hemoglobin, which combines readily with oxygen, the red corpuscles are able, while the blood is passing through the lungs, to get oxygen from the air and carry it to the tissues. The physical forces which control the taking in and giving up of oxygen by the blood will be discussed in connection with respiration. Hemoglobin, when holding oxygen in combination, is called *oxyhemoglobin* and is of a red color. After it parts with its oxygen, the hemoglobin and, consequently, the blood are of a bluish hue.

459. SIZE OF ERYTHROCYTES.—The red corpuscles vary in size from $\frac{1}{3000}$ to $\frac{1}{4000}$ of an inch in diameter and $\frac{1}{12000}$ of an inch in thickness.

460. NUMBER.—The average number of erythrocytes in a cubic millimeter of blood is about 5,000,000 in men and 4,500,000 in women, but the number varies, even in health, and it sometimes becomes very greatly reduced either as the result of (1) loss of blood, as by hemorrhage; (2) abnormally rapid destruction of the cells as the result of disease of the spleen, the absorption of

[1] The red corpuscles were formerly thought to consist of a cell membrane enclosing a fluid substance.

bacterial toxins, certain drugs, or other substances that cause hemolysis; (3) a deficient production of new cells—this is often due to disease of the bone marrow. The condition produced by a deficiency of erythrocytes is known as *anemia*. Anemia will be present also if the cells have not their normal quantity of hemoglobin, even if there is no deficiency in number. This often happens when, due to loss of cells, new ones are produced at a rapid rate and when the bone marrow is diseased.

461. Life History of the Erythrocytes.—The red corpuscles are constantly undergoing disintegration in different parts of the circulatory system and, especially in the spleen. The pigment which gives color to the bile is derived from worn-out cells which the liver takes from the blood and discards after splitting off the iron to save for further use. New cells are formed, in intrauterine life, in the liver and spleen and, later, in the red marrow of the bones. After birth, the latter is usually the only seat of their production. They are formed, by cell division, from large nucleated red cells called *erythroblasts*, but, before entering the circulation, cells lose their nuclei. Iron is necessary for the production, as well as for the functioning, of hemoglobin.

462. White Corpuscles.—These, known also as leucocytes and, certain ones, lymphocytes, are nearly spherical masses of protoplasm containing a nucleus that, in some leucocytes, is multilobed. They have no cell wall. The nucleus and cyto-

plasm of different cells show considerable differences when viewed under the microscope and they cannot all be stained with the same dyes. Based upon such differences, leucocytes have been classified as follows:

463. The multilobed leucocytes are classed as *polymorphonuclears* and those which can be dyed with neutral dyes as *neutrophils*. Leucocytes which can be stained with basic dyes, as *basophils* and those which can be stained with eosin, as *eosinophils*. Those with a simple nucleus are called *mononuclears* or *transitionals*. The lymphocytes are classed as *large* and *small*.

464. NUMBER.—In the blood of a healthy adult the average number of leucocytes in each cubic centimeter of blood is between 7000 and 9000, which means about 4 to every 666 of the red. This number, however, varies considerably in the course of the same day, even in health; for instance, shortly after a full meal the number may be increased one-third and then fall again to normal in the course of two or three hours.

465. LEUCOCYTOSIS.—In many abnormal conditions the number of leucocytes becomes very greatly increased, and in some diseases a knowledge of change in their number is of great assistance in judging the progress of the disease and in diagnosis. An increase in number is spoken of as *leucocytosis*.

466. ORIGIN.—The polymorphonuclear neutrophils, eosinophils, and basophils are derived

from cells—*myeloblasts*—in the bone marrow; the mononuclears from cells in the lymph tissue and the spleen; the lymphocytes from *lymphoblasts* in the lymph glands.

467. Principal Differences between Erythrocytes and Leucocytes.—(1) The leucocytes have no pigment nor hemoglobin and, therefore, are colorless and cannot carry oxygen to the tissues as do the red corpuscles. (2) Under normal conditions the leucocytes are present in the blood in far smaller numbers than the erythrocytes, but they are larger than the latter. (3) The erythrocytes are peculiar to the blood, and under normal conditions are seldom found in other parts of the body. They have no power of spontaneous movement, but are carried along in the blood stream. The white cells, on the other hand, by virtue of their amœboid motion[1] can pass through the walls of the capillaries, and are found in the lymph, chyle, the spaces of the connective tissues, and in pus, when this substance forms as the result

Fig. 83.—Amœboid movements.

[1] Amœboid Motion. The white cells move as does the microscopically small animal known as the amœba, hence the name of their movement If a drop of blood be examined under the microscope the white cells will be seen to be constantly changing their shape, as in Figure 83. In this way they can become elongated and pass through the walls of the blood-vessels or send out processes and surround bacteria, etc.

of suppurative processes. (4) The functions of the leucocytes are quite different from those of the erythrocytes.

468. FUNCTIONS OF THE LEUCOCYTES.[1]—(1) Leucocytes protect the body from pathogenic bacteria and other foreign organisms by (*a*) ingesting them, (*b*) by the formation of substances that destroy the bacteria. (2) Leucocytes aid in the absorption of fats and proteids from the intestines. (3) They assist in the coagulation of blood.

469. PHAGOCYTES.[2] INFLAMMATION.[3] PUS.—When bacteria or other foreign cells or organisms enter the tissues irritation ensues, the first effect of which will be an increased flow of blood to the part. If the irritation continues, or if it was originally severe, the flow of blood in the part soon begins to slacken, and a condition known as *inflammatory stasis* is produced. The leucocytes then adhere in large numbers to the walls of the capillaries and small veins, and by amœboid movements migrate into the tissues; also, plasma and a small number of red blood-cells pass out of the blood-vessels. The resulting collection of fluid in the tissues is spoken of as *inflammatory exuda-*

[1] The different kinds of white corpuscles are found in the blood in increased number under differing conditions and thus it is thought that different kinds have special functions.

[2] From the Greek, *phagein*—to eat, and *kytos*—a hollow vessel.

[3] The symptoms of inflammation are redness, heat, swelling, pain, and loss of motion. The two first symptoms are due to the increased supply of blood in the part; the three last, principally, to the engorged vessels and the presence of the exudation.

tion, and the general condition as *inflammation*. Some leucocytes, by changing their shape, as in Figure 83, endeavor to engulf or *eat up* the invaders and, because of this action, they are known as *phagocytes*. If the phagocytes succeed, the exudation and all the debris of the struggle—dead tissue cells, bacteria, and blood-cells—will be absorbed and carried away by the blood and lymph. If the phagocytes do not overcome the bacteria, destruction of the former and of body tissue, with production of pus, will ensue. Thus pus consists of blood plasma, a few red cells, many colorless cells, disintegrated tissue, dead and living bacteria, and poisonous substances or toxins produced by the bacteria.

470. OPSONINS.[1]—The victory or defeat of the phagocytes is largely dependent upon substances contained in the blood, called *opsonins*. These substances, the nature of which is as yet little understood, enter into more or less close union with the bacteria, and acting upon them, in some unknown manner, prepare them for digestion by the phagocytes.

471. BLOOD-PLATES.—Very little is known about the third variety of blood-corpuscle, the blood-plates; in fact, it has not even been decided whether they are independent cells or fragments of disintegrated cells. This lack of knowledge is due to two causes: (1) the cells are exceedingly minute, being even smaller than the red corpuscles;

[1] From the Latin *opsono*—I cater for, or prepare food for.

(2) they disintegrate so rapidly after removal from the circulating blood that it has been impossible to study them under the microscope.

472. FUNCTION.—The blood-plates are thought to take an active part in the initiation of coagulation. It is supposed that in the process of disintegration they give rise to a substance known as thrombokinase which, with the aid of the calcium salts in the blood, changes a substance called *prothrombin*, that exists in the blood-plasma—into thrombin—see paragraph 484.

473. PROTEINS OF THE BLOOD PLASMA.—The principal proteins of the plasma are: serum albumin,[1] serum globulin (also known as paraglobulin), and fibrinogen.

474. SERUM-ALBUMIN.—This protein belongs to the same class of albumins as that found in the white of egg. It is thought to be derived from the digested proteins of food, and to be the main source of protein building material for the tissues.[2]

475. SERUM-GLOBULIN.—There are many theories advanced as to the nature of serum-globulin. One of the most common is that it is derived from broken-down body tissue, disintegrated leucocytes, and other formed elements of the blood.

476. FIBRINOGEN.—This is a protein of the globulin type. Its origin is uncertain, but the

[1] The nature of albumins and globulins is explained in the Glossary.

[2] This will be referred to again in the chapter on metabolism.

results of numerous experiments seem to indicate that at least part of it may be formed in the liver. When blood is shed under favorable conditions,[1] fibrinogen is changed to an insoluble and therefore solid protein known as fibrin, a substance which is essential to the clotting of blood.

477. EXTRACTIVES CONTAINED IN THE BLOOD PLASMA.—The so-called extractives of blood are substances other than the proteins already described which may be extracted from dried blood by water, alcohol, or ether. The most important ones are:

1. Fats, which, except after a meal, are present only in very small quantities.

2. Glucose, present in the blood under normal conditions in the amount of 0.1 to 0.15 per cent. The quantity is often increased temporarily after eating a large amount of sugar and, unless relieved by dietetic treatment, permanently in the disease known as *diabetes*.

3. Nitrogenous Extractives—these are chiefly protein waste matter. The most important are urea, creatin, uric, and other acids.

478. THE MINERAL MATTER OF THE BLOOD PLASMA.—The mineral substances of the blood consist chiefly of:

Chlorides Carbonates Sulphates Phosphates	of	Sodium Potassium Calcium Magnesium Iron

[1] Described in paragraph 486.

These are derived: (1) from food, (2) as the result of certain chemical reactions that are continually going on in the body.[1]

479. GASES—The gases contained in the blood are: carbonic acid, oxygen, and nitrogen. Arterial blood contains relatively more oxygen and less carbonic acid[2] than venous blood; but even in the arteries there is more carbonic acid than oxygen, as can be seen by the following figures:

	OXYGEN.	CARBONIC ACID.	NITROGEN.
Arterial blood	20 vol. per cent.	39 vol. per cent.	1 to 2 vols.
Venous blood	8–12 " " "	46 " " "	" " " " [3]

480. INTERNAL SECRETIONS, ENZYMES, IMMUNE BODIES, ETC.—There are in the body a number of substances that were quite unknown until recent years, and of which even yet knowledge is limited beyond the fact that some of them play an important part in the processes of digestion and metabolism, and others in guarding the body against pathogenic bacteria. These substances are: (1) *Internal secretions*—these will be described in the chapter devoted to the ductless glands—and (2) *enzymes*—for description see the chapters on digestion and metabolism.

481. ANTIBODIES.—In addition to the phagocytes and opsonins, which have been already

[1] Described in paragraph 796.

[2] Carbon dioxide—H_2O.

[3] *Handbook of Physiology*, page 162. Kirk. Wm. Wood & Co.

described, the blood contains various other defensive substances known collectively as antibodies. The majority of these antibodies, unlike the phagocytes, are specific in their action; *i. e.*, each variety will protect the body against only one special form of bacteria or toxin; *e. g.*, the antibody for typhoid will not give protection against diphtheria. It is not yet known positively whether these antibodies are a natural constituent of the blood or if they are developed only during an attack of the disease; but they certainly are greatly increased by this cause, which accounts for the immunity against certain diseases of bacterial origin afforded by one attack. Just how these antibodies come into existence is not positively known. The most generally accepted theory of the present day is that advanced by Prof. Ehrlich[1] called the *receptor theory*. It assumes that in all the cells of the animal body there are certain chemical substances that he calls *cell-receptors* which have the power of taking from the blood or lymph the material which they require for their nourishment, and that these receptors will combine with the bacterial substances just as they do with the food molecules; but the former, unlike the food material, destroy the receptors.[2]

[1] Director of the Royal Prussian Institute for Experimental Therapy at Frankfort-on-the-Main.

[2] It is thought that when a certain limit of anchoring of receptors by toxins has taken place the cell perishes, and if a sufficient number of cells with vital functions to perform are destroyed, death of the individual follows.

Unless injury to the cell is carried too far, however, not only will regeneration of the substance known as receptors take place, but a supply in excess[1] of the cells' needs will be formed, and the surplus will be discharged into the blood-stream. These free receptors constitute the antibodies known as antitoxins,[2] antibacterial[3] substances, etc. The anti-bodies thus formed vary both in their composition and in their action on toxins, etc., but the primary means by which they protect the body is by uniting with the toxic substances, thus preventing their union with tissue cells. The power of the body thus to defend itself from disease is spoken of as *immunity*.[4]

[1] Over-production of cells is very common in the process of tissue repair; *e. g.*, the over-abundant growth of cells in granulating wounds.

[2] Antitoxin substances act upon the poison secreted by bacteria and neutralize its toxic property.

[3] Antibacterial substances affect the bacteria themselves and destroy them or paralyse their action.

[4] Immunity against certain diseases may be acquired also by receiving injections of blood-serum containing antibodies taken from an animal that has had the disease against which the individual wishes to be protected, or by being inoculated by preparations containing either dead bacteria or bacteria that have by some means been rendered less virulent, as for instance the vaccine of small-pox, in which the organism to which small-pox is due is weakened by passage through another species of animal. Immunity gained by the first method is termed passive *immunity, because* the recipient's body has taken no active part in the preparation of the antibody, it having been formed in the body of another animal. Immunity obtained by the second method is called *active immunity*, since the individual's body itself forms the antibody as the result of the invasion of the

Clotting or Coagulation of Blood

482. NATURE OF PHENOMENA.—One of the most characteristic properties which the blood possesses is that of clotting or coagulation. The phenomena may be observed under the most favorable conditions in blood which has been drawn into an open vessel. They are as follows: In about two or three minutes at the ordinary temperature of the air the fluid is seen to become semi-solid or jelly-like on the surface and at the sides of the vessel in which it is contained, and the change gradually extends throughout the entire mass. This solid mass so formed is called the *clot*. If the clot be watched for a few minutes a light, straw-colored fluid may be seen appearing on the surface; this fluid is known as the *serum*. It gradually increases in quantity and soon begins to exude from the sides and under surface of the clot, while the clot as gradually shrinks and grows harder. This exuding of the serum from the clot continues for from thirty-six to forty-eight hours.

483. PHYSIOLOGY OF CLOTTING.—The blood circulating in the blood-vessels consists, it will be remembered, of: (1) plasma, which is water hold-

bacteria; though owing to the attenuated condition of the bacteria the recipient's health is little affected. Further information regarding the nature, action, and preparation of antitoxins can be obtained from almost any recently published bacteriology or materia medica. *General Bacteriology*. Jordan. W. B. Saunders Co. is particularly recommended.

ing in solution a number of soluble substances, and (2) corpuscles held in suspension in the plasma. One of the soluble substances of the plasma is fibrinogen and this, when blood is shed, is changed to an insoluble substance called fibrin, which, being insoluble, is precipitated. The precipitate consists of a meshwork of fine threads which gathers into its substance the corpuscles and a large portion of the solid substances of the plasma. Thus, the serum represents the plasma, minus the majority of its solids and corpuscles. It will, however, contain a considerable number of white corpuscles, because these, by virtue of their amœboid motion, pass out of the clot during its contraction. The contraction of the clot is due to the shrinking of the threads of the fibrin meshwork.

484. Origin of Fibrin.—It is now the generally accepted belief that fibrin, an essential agent in the clotting of blood, is derived from the soluble fibrinogen by the action of a ferment known as *thrombin*, that, as stated in paragraph 472, is formed from prothrombin by the action of thrombokinase, a substance set free from leucocytes and blood-platelets on their disintegration.

485. Advantage of the Clotting Property of Blood.—The clotting property of blood is of great value, for upon it depends very largely the arrest of hemorrhage, and nearly all the procedures used to prevent the escape of blood from severed vessels are directed toward hastening the

formation of a clot. There are abnormal conditions of the blood which prevent its clotting readily, and an individual whose blood is so constituted may bleed to death from a very slight wound. A lack of calcium salts in the blood is thought to be one of the most common causes of this condition.

486. CONDITIONS WHICH PROMOTE AND RETARD CLOTTING.—Clotting of the blood is assisted by:

(1) Injury to the walls of the blood-vessels;
(2) Contact with foreign substances; thus, clotting will be accelerated if gauze or like substance is put into a wound, and a clot may form in a blood-vessel if air is introduced;
(3) Contact with a rough surface;
(4) Heat—about 116° to 120° F.
(5) Rest.

487. The reason these conditions accelerate clotting is thought to be that, with the exception of rest, they hasten the disintegration of leucocytes and blood-platelets, and, consequently, the formation of thrombin.

488. CLOTTING MAY BE PREVENTED OR RETARDED BY:

(1) Contact with the living tissue—as the interior of the blood-vessels;

(2) The absence of calcium salts;

(3) Cold retards coagulation; nevertheless, cold is often used to arrest hemorrhage because it contracts the blood-vessels;

(4) The addition to the blood of neutral salts, of strong acid or alkalies, oil or other viscid substances, certain organic ferments as trypsin and pepsin, snake venom, leech extracts, a large quantity of water;

(5) Removal of the fibrin. If normal, fresh blood is stirred for a few minutes after its removal from the body, the fibrin will collect on the stirring utensil in a shredded mass. The remaining liquid, which looks like unaltered fresh blood, will not clot. It is called the *defibrinated blood.*

489. Why Blood Does not Clot within the Living Blood-Vessels.—Blood seldom clots within the living blood-vessels. Why it does not is still a matter of conjecture. Some of the theories advanced are:

1. That in the living blood-vessels the leucocytes and blood-plates do not disintegrate in sufficient numbers at a time to allow of thrombin being formed, so that circulating blood does not contain thrombin.

2. That the circulating blood does contain at least a small amount of thrombin, but that the body has safeguards which diminish its activity. Some investigators think that the thrombin is destroyed in the liver; others, that the lining of the walls of the heart and blood-vessels secrete an anti-thrombin substance.

490. Why Intravascular Clotting Does Sometimes Occur.—Occasionally the blood does

clot within the vessels. Some of the causes for this are:

1. Entrance of air into a blood-vessel. The air, if not absorbed, will act as a foreign substance and cause disintegration of the blood-plates and leucocytes, and consequent formation of thrombin and clotting.

2. Injury to the internal wall of a blood-vessel, as, for instance, by a ligature, or as the result of disease, as in phlebitis.

491. THROMBUS[1] AND EMBOLUS[2].—A clot formed in a blood-vessel is called a *thrombus*. It is a source of great danger to the individual in whose veins it forms, because, though it may be broken up and disappear, it is likely to be carried to some point in a main vessel where its presence may cause instant death. A thrombus that is moved from the place of its formation is termed an *embolus*.

492. REGENERATION OF BLOOD AFTER HEMORRHAGE.—A large portion of the entire blood of the body may be lost suddenly by hemorrhage without producing a fatal result. Recovery has been known to occur after the loss of a quantity of blood amounting to as much as three per cent. of the body weight, especially when the lost blood has been at once replaced by some solution such

[1] From the Greek *thrombus*—a lump, a piece.

[2] From the Greek *embolus*—a wedge. The word is often used to designate one thing that is inserted in another and moves therein; hence its connection in the present sense.

as physiological salt solution,[1] *i. e.*, sodium chloride 0.7 to 0.9 per cent. When given to replace lost blood the solution is usually injected into a vein, and the operation is called *intravenous infusion*. The benefits derived from such an injection are: (1) prevention of injury to the tissue cells by loss of water; (2) the circulating blood is brought to a sufficient quantity to maintain normal conditions of pressure and velocity of the heart-beat; (3) it acts as a stimulus to the heart action, by forcing it to take stronger contractions in order to propel the extra fluid so provided into the blood-vessels; (4) the red corpuscles that remain in the vessels are kept in circulation, and complete loss of oxygen to the tissues is thus prevented. The corpuscles lost in the hemorrhage are gradually replaced. The manner in which this is done was described in paragraph 461 of this chapter.

493. Blood Transfusion.—Occasionally instead of injecting physiological salt solution into

[1] A solution used for this purpose must contain one or more of the important salts of the blood, and it must be isotonic with the blood-serum; *i. e.*, it must have the same degree of concentration and thereby exert the same degree of osmotic pressure (see Glossary). A less concentrated solution would, by reason of its low osmotic pressure, enter the red blood-corpuscles and cause hemolysis; *i. e.*, breaking down of the cells. B'ood thus acted upon is said to be laked, and a solution that will cause such a condition is said to be hypotonic to blood-serum. On the other hand a more concentrated solution, *e. g.*, one containing a larger per cent. of salt than 0.7 or 0.9 per cent. would, by reason of its high osmotic pressure, extract water from the corpusc'es and cause them to shrivel. Solutions which exert a higher osmotic pressure than blood-serum are termed hypertonic.

a patient's vein, blood from the vein of another individual is allowed to flow into one of the patient's veins. This operation is called *blood transfusion.* For several reasons this operation is not often done; one reason is that it is attended with considerable danger; *e. g.*, the injected blood is likely to form sufficient thrombin to cause clotting; also, the blood of one individual is often hemolytic to that of another. At one time it was thought that the blood of the lower animals could be transfused into the veins of human beings; but experiments soon proved that the blood of one species of animal is nearly always hemolytic to that of another species.

Lymph

494. NATURE.—Lymph is a colorless or slightly yellow-colored fluid that, with a few exceptions, resembles blood in its composition, the essential differences being:

(1) An absence of erythocytes and blood-plates;

(2) A lower specific gravity, or, in other words, a lower content of solid matter. This lower specific gravity[1] is of great importance in regulating the passage of lymph to and from the blood and lymph-vessels and the tissues.

(3) Especially in the lymph contained in the

[1] The specific gravity of blood varies from 1041 to 1067; that of lymph from 1012 to 1022.

lacteals[1] there is a higher per cent. of fat than in the blood;

(4) Lymph coagulates more slowly and less firmly than blood.

495. WHERE FOUND.—Lymph is found in the lymphatic vessels, and in practically all spaces in the subcutaneous tissues.

496. DERIVATION.—Lymph is derived directly from the blood. It is, in fact, blood plasma plus some white corpuscles and minus some solid substances, which have passed through the walls of the capillaries into the tissues. The forces which cause it to do so and later to return to the blood will be described in Chapter XIV.

497. FUNCTIONS.—(1) Lymph diffuses widely through all the tissues of the body, and the latter take from it the nutrient they need. (2) It collects and carries to the heart, *via* the lymphatic vessels and veins, the waste material formed in the tissues as the result of the perpetual chemical activities occurring there. Some of this waste matter can be used again, and is carried by the blood to parts of the body for this purpose. Some of it is of no further use to the body, and is carried to the kidneys, skin, or lungs, to be excreted.

[1] Latin *lacteus*, from *lac*—milk. The lymphatic vessels contained in the walls of the intestines which absorb the fat. So called because their contents, especially after a meal, are milky looking.

CHAPTER XII

THE VASCULAR SYSTEM—*Continued*

Structure, Location, and Function of the Organs of the Blood- and Lymph-Vascular Systems.

498. ORGANS CONSTITUTING THE BLOOD-VASCULAR SYSTEM.—As stated in the preceding chapter, the blood-vascular system consists of the heart, arteries, capillaries, and veins.

499. FUNCTION.—The heart pumps the blood into the arteries; the arteries carry the blood to the capillaries; the veins carry it from the capillaries back to the heart. The capillaries are, in a way, the main factor in the whole vascular system as it is, due to conditions to be discussed later, while passing through these vessels that the blood performs its ultimate function, namely, the giving off to the tissues of the substances they require for their nourishment, etc., and the collection of waste matter. Also, it is while flowing through the capillaries of the excretory organs that the waste substances are eliminated.

Anatomy of the Heart

500. SHAPE AND POSITION.—The heart is a hollow muscular organ of conical shape. It is situated

in the thoracic cavity, between the right and left lungs, and behind the lower two-thirds of the sternum, with its lower edge resting upon the diaphragm. It lies obliquely and extends farther to the left than to the right of the median line. Its broad part, or base, points upward, backward, and to the right; its pointed portion, or apex, is directed downward, forward, and to the left. The lower end of the apex comes in contact with the chest wall, and its beat can be felt in the fifth intercostal space,[1] about one and a half inches to the left of the mid-sternal line.

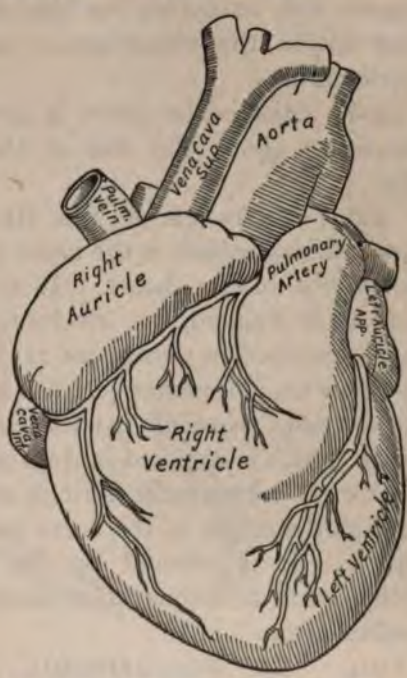

FIG. 84.— Front view of the heart.

501. ATTACHMENTS.—The heart is, as it were,

[1] Between the fifth and sixth ribs. A little below and to the inner side of the nipple of the left breast.

suspended in the chest by the large blood-vessels which proceed from it. It has no other attachments and, excepting for this connection, it lies free within the membranous sac known as the pericardium.

502. SIZE.—The heart is generally estimated as being about the size of the owner's closed fist.

503. SUBSTANCE OF THE HEART: MYOCARDIUM.—Myocardium is the name given to the main substance of the heart. It is composed very largely of striated, but involuntary, muscular tissue (described in paragraph 215), of blood-vessels, lymphatics, and nerves. It has a small amount of fatty tissue, especially at its base, and of fibrous tissue which is disposed in rings around the orifices that exist between the auricles and the ventricles, and at the origin of the aorta and the pulmonary artery. It is covered by the *pericardium* and lined with a serous membrane known as the *endocardium.*

504. THE PERICARDIUM[1]: STRUCTURE AND POSITION.—The conical-shaped membranous sac enclosing the heart and known as the pericardium consists of two distinct parts: (1) an outer external membrane which is attached by its lower border to the diaphragm, by its upper posterior surface to the large blood-vessels emerging from the heart, and by its front surface, by means of two fibrous bands, to the sternum; (2) an inner serous mem-

[1] From the Greek *perikardion*—about the heart.

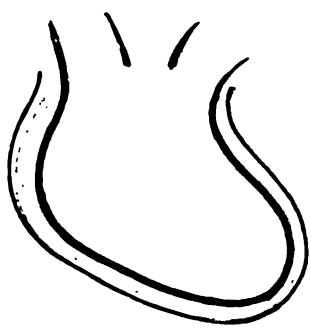

FIG. 85.—Arrangement of pericardial sac.

brane which lines the fibrous layer, but at the parts where the latter is attached to the large blood-vessels, passes forward and down over the heart, thus forming as it were a closed sac around that organ, as shown in Fig. 85; the red lines indicating the walls of the heart and blood-vessels; the black, the outer layer of the pericardium; the blue, the inner serous layer. The portion of the serous membrane lining the fibrous coat of the pericardium is called the parietal layer; and that covering the heart, the visceral or epicardium layer.

505. FUNCTIONS OF THE PERICARDIUM.—The sac-like character of the pericardium makes an interstice between the heart and the lungs and diaphragm, and prevents the movements of these organs interfering with the heart movements. The serous layer secretes a viscid fluid which lubricates the two surfaces and thus enables them to glide smoothly over each other during the movements of the heart.

506. ENDOCARDIUM.—The endocardium is a smooth, simple form of serous membrane which lines the heart and enters into the formation of its valves. It is directly continuous with the lining of the blood-vessels.

507. CHAMBERS OR CAVITIES OF THE HEART.—The interior of the heart is divided longitudinally, by a muscular partition, into two chambers or cavities—a right and a left, and each of these cavities is subdivided into an upper and a lower

chamber. The two upper cavities are known as the *auricles* and the two lower ones as the *ventricles*.

508. ORIFICES OF THE HEART.—Normally after birth there are ten orifices in the heart, not including the small openings in the right auricle to receive the blood returning from the *myocardium*. There is one between each auricle and ventricle; one in the left ventricle which connects with the aorta[1]; one in the right ventricle which opens into the pulmonary[2] artery; four in the left auricle—one for each of the four pulmonary veins; two in the right auricle—one for the superior and the other for the inferior vena cava[3]; also as previously stated there are in the right auricle a varying number of small openings connected with the veins returning the blood from the myocardium or heart substance. In the fetus there is an orifice between the two auricles, but unless this closes at birth the infant usually dies in a short time. There is, normally, no opening between the two sides of the heart after birth.

509. PURPOSE OF THE BLOOD-VESSELS OPENING INTO THE HEART.—The aorta receives the blood that is to go to all the tissues of the body for their nutrition, etc.; the pulmonary artery, that which must go to the lungs to exchange its excess carbon dioxide for oxygen. The pulmonary

[1] From the Greek *aorte*—to carry.
[2] From the Latin *pulmono*—lung (relating to the lungs).
[3] Latin, hollow veins.
This will be further discussed in connection with the circulation.

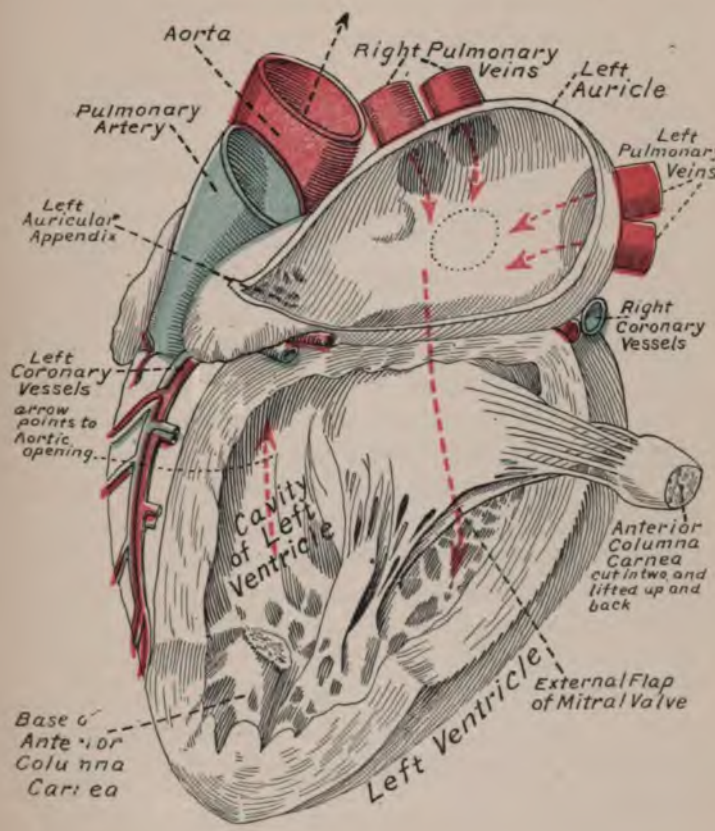

FIG. 86.—Left auricle and ventricle, the back wall of each has been removed.

veins bring back the blood from the lungs—two from the right and two from the left lung. The superior vena cava returns the blood from the upper part of the body, and the inferior vena cava, that from the lower portion. Thus it will be seen that the left side of the heart contains the blood that has been aërated and is ready to go through the system; and the right side, the blood that must go to the lungs to exchange some of its carbon dioxide for oxygen.

510. NAMES AND LOCATION OF THE VALVES OF THE HEART.—Each of the auriculo-ventricular orifices is guarded by a valve, as are also the openings into the aorta and the pulmonary artery. The valve between the left auricle and ventricle is called the bicuspid[1] or mitral[2] valve; that between the right auricle and ventricle is known as the tricuspid[3]; the one protecting the opening to the aorta and the one guarding the pulmonary artery bear the same name and are known as the semilunar[4] valves. The opening into the inferior vena cava is partly covered by a membrane known as the Eustachian[5] valve, but the other veins *at their connection with the heart* have no valves.

511. STRUCTURE OF THE VALVES.—The valves

[1] Latin prefix *bi*—two and *cuspis*—a point, so called because it has two points.

[2] So called because it was thought to be the shape of a bishop's miter.

[3] Latin prefix *tri*—three and *cuspis*—a point.

[4] From the Latin *semis*—half and *luna*—the moon.

[5] Called after Eustachius, a famous anatomist.

of the heart are composed mainly of fibrous and elastic tissue enveloped by the endocardium. The tricuspid, as its name signifies, has three cusps or flaps, and the bicuspid has two. The flaps of each of these valves are attached at their base to a fibrous ring which encircles the auriculo-ventricular orifices so that they form an annular membrane around the orifice. The free end of each flap falls downward into the ventricle when the valve is not in action, *i. e.*, while the blood is flowing, through into the ventricle. The ventricular surface[1] of each flap is attached by slender tendinous fibers called the *chordæ tendineæ* to small muscular projections called the *musculi papillares*[2] which cover a portion of the inner surface of the ventricles. These *musculi papillares* are elastic and pliable, and prevent the contractions of the heart interfering with the action of the valves, as they would if the chordæ were attached directly to the walls of the ventricles. The semilunar valves each consist of three flaps of semilunar—*i. e.*, half-moon—shape. The convex border of each flap is attached to a fibrous ring which encircles the openings between the heart and arteries, and the free border, which is slightly concave, projects into the artery. On the edge of this border is a fine fibrous cord, and in the center of the cord a small nodule known as the *corpus Aranti.*[3]

[1] The surface of the flap facing the ventricle.
[2] From the Latin *papilla*—a nipple.
[3] Body of Arantius.

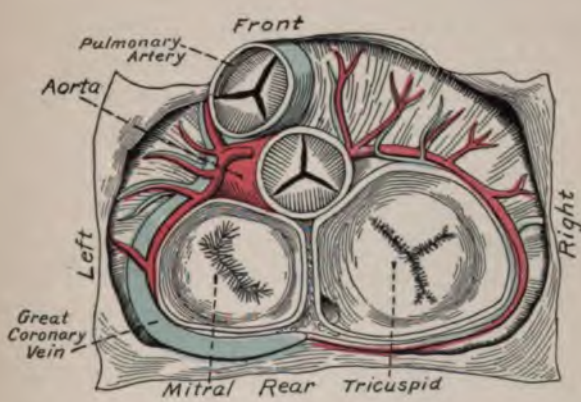

FIG. 87.—Valves of the heart and great arteries viewed from above, the auricles have been removed.

512. Purpose and Mechanism of the Valves.—The valves serve to prevent the regurgitation of blood after it has passed from the auricles into the ventricles, and from the ventricles into the arteries. While the blood is flowing through a valve the free edges of its flaps are pointed in the direction of the blood current. When the cavity or vessel into which the blood is flowing is filled, the blood gets behind the flaps and they float up and close the orifice. The chordæ tendineæ prevent the flaps of the bicuspid and tricuspid valves floating up too far into the auricles which, as they are comparatively large, they would be likely to do were it not for this restraint. The corpus Aranti on the edges of the flaps of the semilunar valves secure firm closure of those valves.

513. Blood Supply of the Heart.—The blood contained within the chambers of the heart does not nourish the heart substance further than the endocardium. It is, therefore, supplied with blood-vessels derived from the *right* and *left coronary arteries*. These arteries were so named because they encircle the heart like the band of a crown.

514. Nerve Supply.—The heart receives its nerve supply from the cardiac plexuses which are distributed freely both on its surface and in its substance. The plexuses are formed partly from nerves derived from the sympathetic system, and partly from branches of the two cranial nerves

known as the vagi. Stimulation of the sympathetic fibers accelerates and increases the force of the heart-beat. They are therefore called *cardiac accelerators* or *augmentors*. Stimulation of the vagi, on the contrary, inhibits the rate of the heart-beat, therefore these are known as *cardiac inhibitors*. The heart is supplied also with sensory fibers, the function of which is not clearly understood, but it is thought that the pain which occurs in certain pathological conditions is due to their stimulation.

The Arteries

515. DERIVATION OF NAME.—The arteries were so named from two Greek words, *aër*—air, and *tereo*—to watch over; because, owing to their elastic nature, they force their contents into the veins at the time of death, but nevertheless retain their shape; and the ancient anatomists, finding that in the dead bodies they examined the arteries were empty of blood, conceived the erroneous notion that they were designed for the circulation of air through the system.

516. STRUCTURE OF THE ARTERIES.—The walls of the arteries are composed of three coats termed the *external*, *middle*, and *internal*. The external coat consists mainly of white and yellow—elastic—fibrous tissue, the fibers of which run longitudinally. This coat serves to give strength to the vessels and, being only slightly elastic, prevents

their undue dilatation. The middle coat is constructed of muscular and elastic fibrous tissue, the fibers of which, being arranged transversely, encircle the vessels. This coat, which is much thicker in the larger than in the smaller arteries, gives the vessels the elastic property that is so essential to their proper functioning. In old age, and sometimes as the result of disease, the arteries lose much of their elasticity and a condition known as *arteriosclerosis* ensues.[1] This interferes with the proper circulation of blood in the tissues and, consequently, the tissue changes characteristic of old age are produced. The inner coat, or lining of the arteries, which is continuous with the endocardium lining the heart, consists of a layer of elastic tissue covered with a delicate simple form of serous membrane. This coat provides a smooth polished surface over which the blood can flow without interference or friction, which is most essential, friction being one of the causes of the clotting of blood.

517. Size of the Arteries.—The largest arteries of the body are those connected with the heart, the aorta and the pulmonary artery. They measure in the adult about 30 *mm.* in diameter at their largest part, that is, at their connection with the heart. Every branch arising from these two arteries and every sub-branch of the main branches is smaller than the artery from which it springs, and all arteries grow smaller toward their

[1] Hardening of the arteries.

distal end, and gradually losing the characteristic artery structure merge into the capillaries. Small arteries are called *arterioles*.

518. Blood Supply of the Arteries.—The walls of the arteries, with the exception of the internal coat, are not nourished by the blood flowing through the vessels, but are supplied with minute arteries, capillaries, and veins. These vessels are called *vaso vasorum*, *i. e.*, the vessels of the vessels.

519. Nerve Supply.—Arteries are also supplied with nerves which are derived chiefly from the sympathetic, but also from the cerebro-spinal system. They form intricate plexuses upon the surface of the larger vessels, and from these plexuses branches enter to the muscular coat of the vessels, and others pass onward to supply some of the smaller arteries. These nerves are called the vaso-motor nerves. They regulate the caliber of the blood-vessels and consequently, the blood supply to the tissues.

520. Nature and Purpose of Sheaths.—The majority of the large arteries are with an accompanying vein, and sometimes a nerve, enclosed in firm connective tissue. The vessels are attached to this membrane, which is called a sheath, by delicate areolar fibers. A sheath helps to support and to hold vessels and nerves in position.

The Veins

521. Structure.—The structure of the veins is very similar to that of the arteries, the main

differences being: (1) the walls of the veins have less elastic tissue and are thinner; (2) the majority of the larger veins have valves in their interior, and the arteries, except the aorta and the pulmonary artery at their connection with the heart, have not.

FIG. 88.—Valves of veins *A* shows a vein cut open between the segments of two valves. *B* shows appearance of valves closed and open.

522. NATURE AND MECHANISM OF THE VALVES OF THE VEINS.—The flaps of the valves of the veins are semilunar in shape, and they consist of a reduplication of the inner coat of the vein strengthened by connective tissue and elastic fibers. They are generally placed in pairs, but in some of the larger veins there are as many as three or four flaps. They are attached to the walls of the veins in much the same manner as the semilunar valves of the heart are attached to that organ, viz., by their convex border; their free end, while the blood is flowing through, being flattened against the wall of the vein, but pointing toward, instead of away from the heart like the flaps of the valves between the heart and the arteries. As the space between two valves is filled the flaps float up and coming together form a wall which prevents the regurgitation of the blood and thus keeps it

flowing in the right direction, *i. e.*, toward the heart.

523. Veins in which the Valves Are Most Numerous or Absent.—Valves are most numerous in the veins of the extremities, and more so in those of the legs than in those of the arms. They are absent in the majority of very small veins, in the superior and inferior vena cava, in the portal, renal, hepatic, and pulmonary veins, and in those veins not subjected to muscular pressure as those in the interior of the cranium, vertebral column, and bones.

The Capillaries

524. Size.—The capillaries[1] are exceedingly minute vessels, varying in size from $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch in diameter. Unlike the arteries and veins the capillaries do not increase or decrease in diameter toward their termination.

525. Structure.—The walls of the capillaries are much more simple in structure than those of the arteries and veins. They are very thin and consist of but one coat which is continuous with, and similar to, the inner one of the arteries and veins.

526. Distribution.—The capillaries arise from the innumerable small branches of the arteries and they, like the arteries, give off branches in all directions. They anastomose in such a manner that they form delicate networks in all

[1] From the Latin *capillus*—a hair.

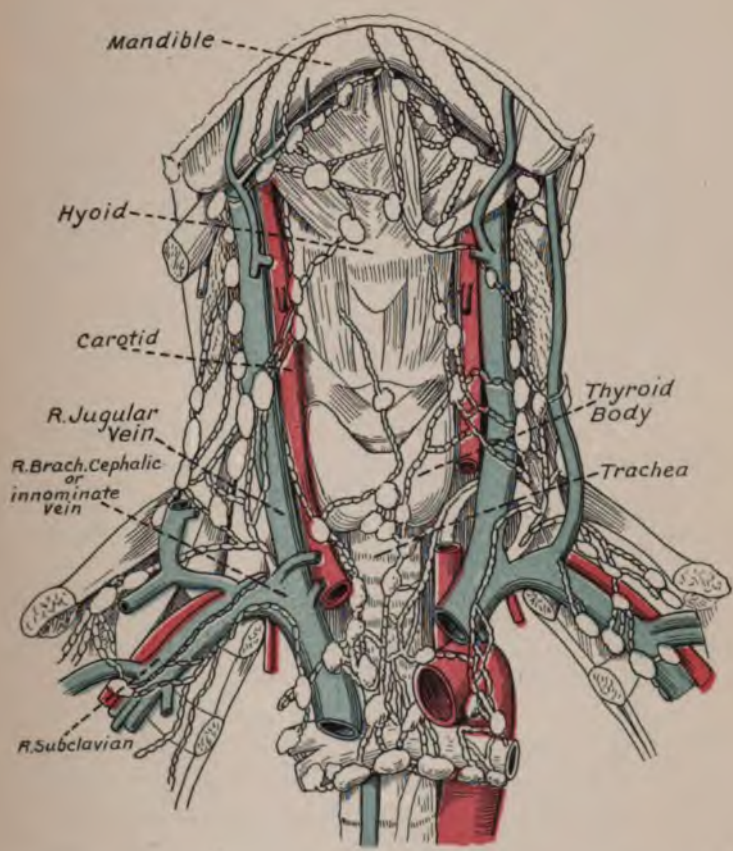

FIG. 89.—The lymph-nodes of the upper part of the thorax and neck.

the tissues of the body excepting the epidermis, hair, nails, cartilage, and the cornea of the eye. In some tissues the capillaries are more numerous than in others; in the liver and lungs there are so many that the spaces between them are smaller than the diameter of the vessels, and also in the derma, mucous membranes, kidneys, brain, and glandular organs, the interspaces are exceedingly small.

Anatomy of the Lymph-Vascular System

527. CONSTITUENTS.—The lymphatic system is usually considered as consisting of the lymph-spaces, the lymphatic vessels, and the lymphatic nodes or glands; but the lymphoid or adenoid tissue, the serous membranes proper, and certain glands, as the thymus (described in Chapter XVI.) have many features in common with the regular lymphatic organs.

528. NATURE AND LOCATION OF LYMPH-SPACES.—In the substance of nearly all the tissues of the body there exist minute irregular spaces known as *lymph-spaces*, into which oozes, from the blood, water and nutrient substances, and from the tissue, waste material resulting from their metabolism. This fluid constitutes the lymph.

529. NATURE AND NAMES OF THE LYMPHATIC VESSELS.—The structure of the larger lymphatic vessels resembles that of the veins and, like the veins, they have valves in their interior which aid very materially in effecting the circulation of the

lymph. Another similarity between lymphatic vessels and veins is that they both begin as minute capillary-like vessels that gradually increase in size and unite to form larger vessels. The smaller vessels resemble the capillaries of the blood-vascular system and are called *lymph-capillaries.* The two larger vessels resulting from the converging of all the smaller ones are called respectively the *right* and *left lymphatic ducts;* the latter is known also as the *thoracic duct.* The lymph-vessels that have their origin in the walls of the small intestine are called the lacteals,[1] because of the milky-looking substance known as chyle which they absorb from the small intestine during the intestinal digestion of food; but their structure is the same as that of the other lymph-vessels.

530. Origin and Distribution of Lymph-Vessels.—The lymph-vessels begin as exceedingly minute capillary-like vessels in the lymph spaces. They are distributed in two distinct sets—a deep and a superficial. The deep lymphatics[2] accompany the large blood-vessels; the superficial are distributed through the subcutaneous areolar tissue. There is no communication between the two sets, but the vessels of each set anastomose freely with each other, and those of the superficial

[1] From the Latin *lacteus*—milky.

[2] Formerly it was thought that the lymphatics at their origin in the lymph-spaces were open vessels; but many physiologists now doubt if this be the case.

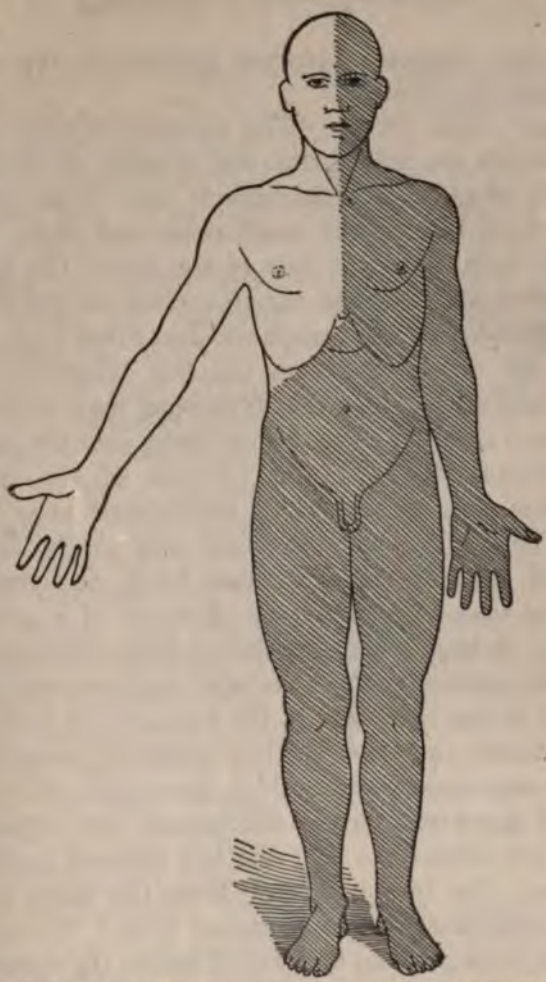

FIG. 90.—The regions whose lymph flows into the right lymphatic duct are suggested by the lighter area; those which are tributary to the thoracic duct by the darker area.

set form frequent intricate plexuses in the subcutaneous tissues.

531. THE DUCTS.—The contents of both sets of vessels are poured into one or other of the two ducts mentioned in paragraph 529. That from the right side of the head, neck, and chest, the right lung, the right side of the heart, the right upper limb, and the upper surface of the liver flows into the right lymphatic duct; that from the rest of the body enters the left lymphatic or thoracic duct. The right lymphatic duct is about an inch or less in length and opens into the right innominate vein at the junction of the right internal jugular and right subclavian[1] vein (see Fig. 89). The thoracic duct is a much larger vessel, being in the adult from fifteen to eighteen inches long and about the diameter of a goose-quill. It begins as a pear-shaped dilatation in front of the second lumbar vertebra and ascends upward at the right side of the aorta to the level of the fourth thoracic vertebra, where it passes behind that vessel, and arching downward and outward opens into the left innominate vein between the left subclavian and the left internal jugular veins. The lymph flowing from the ducts into the innominate veins becomes mixed with the blood in those veins and with it enters the superior vena cava and thence the right auricle of the heart.

532. FUNCTIONS OF THE LYMPHATIC VESSELS.—

[1] Known also as the *brachio-cephalic.*

The lymphatic vessels serve to absorb the lymph and carry it to the heart. The lacteals help in the absorption of digested food products, especially fats, from the intestine.

FIG. 91.—A lymph-node with its afferent and efferent vessels. (Gerrish.)

533. NATURE AND LOCATION OF LYMPH-NODES OR GLANDS.—These are small round or oval bodies situated in the course of lacteal and other lymphatic vessels, through which the chyle and lymph pass on their way to the blood. The nodes consist of a covering or capsule of fibrous tissue from which fibers pass to the interior of the gland and divide it into hollow spaces which communicate freely with each other. These spaces, or *alveoli*, contain the special glandular substance which consists principally of adenoid tissue and leucocytes, and is known as *gland-* or *lymph-pulp*. The pulp does not completely fill the alveoli, and the vacant spaces communicate with each other, forming a tortuous channel through the gland that is

named a *lymph-path* or a *lymph-sinus*. The majority of the nodes have a depression on one side called the *hilum*,[1] through which the blood-vessels enter and leave its interior, and from which the efferent lymphatic vessels emerge. Afferent lymph-vessels enter a node at different parts of its surface and in its interior branch out and form plexuses through the substance. These vessels lose their coats, except the endothelial[2] lining which is continuous with the lining of the lymph-path into which they empty, and from which the efferent vessels arise. The lymph entering the gland by the afferent vessels is thus poured into the sinus which winds through the gland substance, before it enters the efferent vessels.

534. FUNCTION OF THE LYMPH-NODES.—Lymph leaving a node has a larger number of leucocytes than that entering; therefore it has been decided that the formation of leucocytes is one of the functions of these glands; another seems to be that they protect the body from infection by acting as sieves, catching and detaining in meshes of tissue that cross the sinus foreign substances absorbed with the lymph from the lymph-spaces in the tissues. When the foreign matter consists of bacteria, an inflammatory process often ensues, but owing to the large number

[1] From the Latin *hilum*—a depression.

[2] From the Greek *endon*—within and *thele*—a nipple. The name given to the thin layer of secretory cells lining the blood- and lymph-vessels, etc.

of leucocytes present, the bacteria are more likely to be destroyed here than in the tissue, and they do less harm than if they entered the general circulation, as they would were they not detained in the nodes.[1]

535. Number and Location of Nodes.—The number of nodes has been estimated at about 700 of which the greater part are in the abdomen and thorax. The face and neck have a considerable number, the limbs a few, especially in the groin and axilla, the brain case none. They vary considerably in size; the larger ones are about the size of a bean. Some of the nodes frequently referred to are the solitary glands and Peyers patches of the intestine and the tonsils in the pharynx, described in Chapter XVII.

[1] When glands are enlarged or inflamed, they often fail to destroy bacteria and, for this reason, abnormal conditions of the masses of lymphoid tissue known as the *tonsils* make them a source of danger, rather than a protection, to the body. It is thought that the germs producing rheumatism, endocarditis, chorea, and other infectious diseases often gain entrance to the body through diseased tonsils.

CHAPTER XIII

VASCULAR SYSTEM—*Continued*

Names of the Divisions of the Blood-Vascular System. Nature of the Distribution of the Blood-Vessels. Names and Location of the More Important Arteries and Veins.

536. DIVISIONS OF THE CIRCULATORY SYSTEM. —The blood-vessels of the body are arranged into two distinct main systems and an accessory system. The largest of the main systems is that intended for the general or systemic circulation. It provides passage for the blood from the left ventricle of the heart through, practically, all the tissues of the body to the right auricle of the heart. Its purpose is to provide the tissues with the nutrient material, oxygen, etc., that they require and to help gather up the waste matter. The second main system, called the lesser or pulmonary system, contains the blood flowing from the right ventricle of the heart to the lungs and thence back to the heart, to the left auricle. This blood, having been through the system giving up its oxygen and collecting carbon dioxide, passes to the lungs that it may exchange its excess carbon dioxide for oxygen. The accessory system,

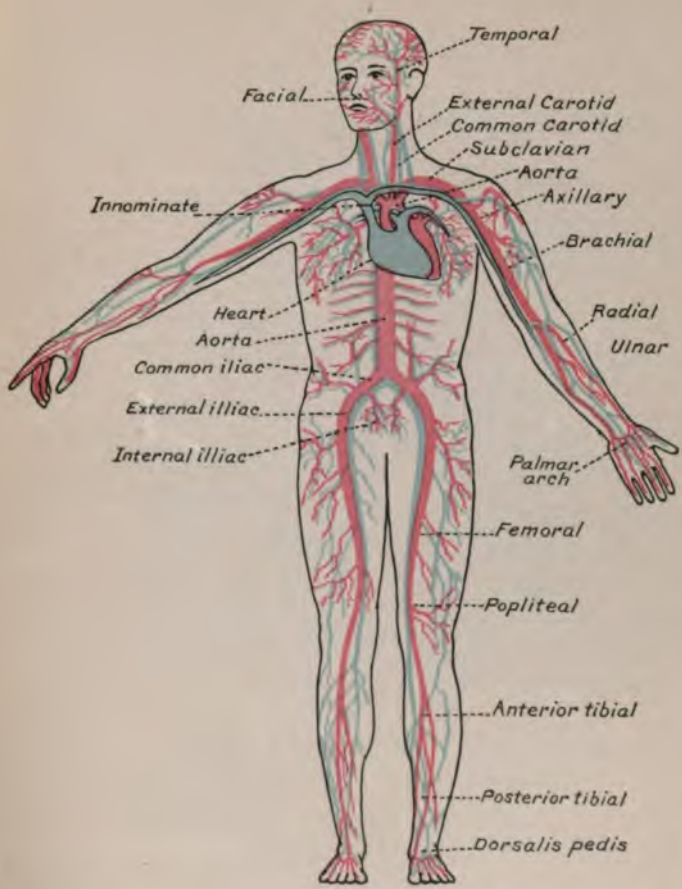

FIG. 92.—Diagram showing plan of distribution of arteries and veins.

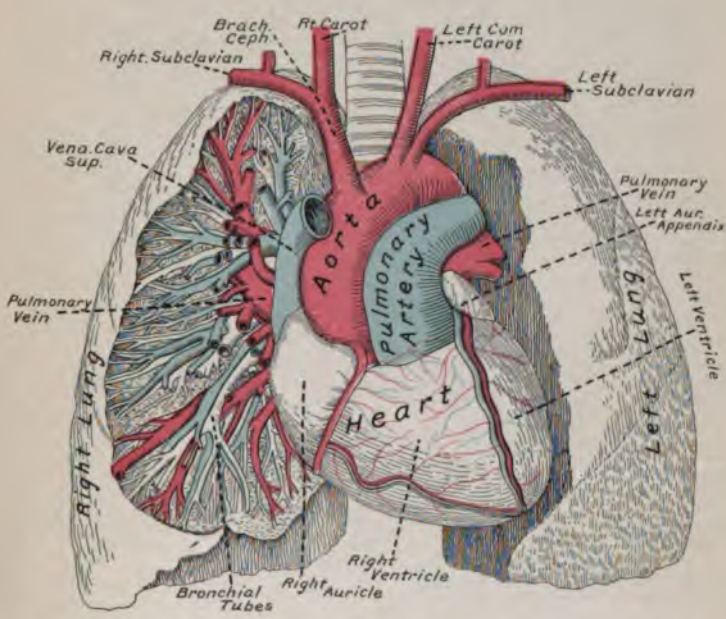

FIG. 93.—The pulmonary artery and aorta. The front part of the right lung has been removed, in order to expose the pulmonary vessels and the bronchial tubes.

known also as the portal system, forms a kind of loop on the general system. Its purpose is to provide passage for the blood from the stomach, intestines, spleen, and pancreas through the liver, so that certain of its constituents (especially those derived from digested food-stuffs) may undergo necessary chemical changes in that organ before being emptied into the general circulation.

FIG. 94.—Diagram showing the formation of large veins by convergence of small, and the branching of veins. (Gerrish.)

537. GENERAL PLAN OF DISTRIBUTION OF BLOOD-VESSELS.—All the arteries of the body originate, directly or indirectly, from the two main trunks, the aorta and the pulmonary artery. Those springing from the aorta constitute the main trunk of the arterial portion of the systemic system. From these branches arteries pass to nearly all the tissues of the body, and the arterioles and capillaries arising from them form networks or plexuses in the tissues as described in paragraph 527. The capillaries gradually merge into veins

which as gradually become larger and run together, so that finally all those from the lower part of the body have united to form the *inferior vena cava*, and those from the upper part of the body, except the ones belonging to the pulmonary system, unite to form the *superior vena cava*. The main trunk of the pulmonary system is the pulmonary artery. This artery bifurcates, *i. e.*, divides into two branches, one of which passes to the right and the other to the left lung. Arteries arise from these main branches which divide and subdivide and dwindle in size, and finally merge into capillaries. The latter gradually assume the characteristics of veins and the veins as gradually grow larger and unite to form, usually, two large veins in each lung which pass to the left auricle of the heart. The distribution of the vessels of the portal system will be described in paragraph 564.

538. The larger blood-vessels are usually deeply seated, or else placed in situations where they are protected from pressure and other dangers. Usually the main artery conveying blood to a part, and at least one of the veins returning it, follow the same course and are often held together in the same investing sheath.

539. ANASTOMOSES OF THE BLOOD-VESSELS.—Many of the branch arteries and a still greater

number of the veins anastomose[1] or inosculate; that is, they unite at their distal ends. This anastomoses of the vessels is of great importance,

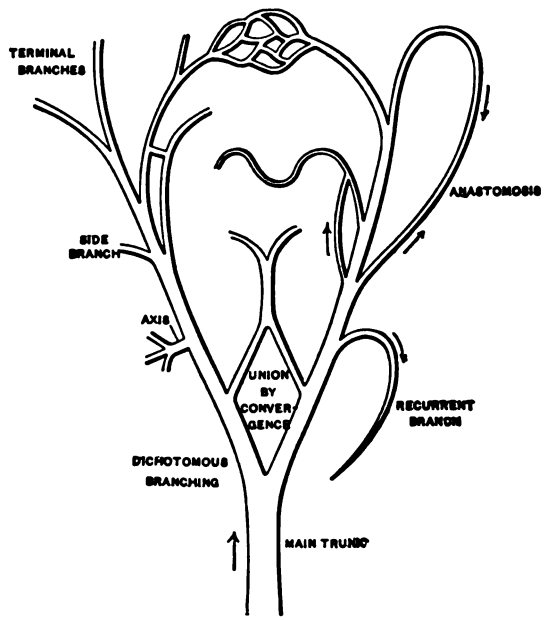

FIG. 95.—Diagram showing the branchings, anastomoses, and confluence of arteries. (Gerrish.)

as it allows of the ligating of veins and arteries in operations and after injuries in which they have been severed, without interfering to any extent with the circulation in the part—the blood being able to flow through the anastomosing vessels.

[1] From the Greek *anastomoō*—to stop the mouth of.

Names and Location of the Larger Systemic Arteries

540. THE AORTA.—The aorta arises from the upper part of the left ventricle, ascends for a short distance, arches backward and to the left side over the root of the left lung, descends within the thorax on the left side of the vertebral column, passes through the aortic opening of the diaphragm into the abdomen, and terminates on a level with the fourth lumbar vertebra by bifurcating and so forming the right and left common iliac arteries. For convenience in description the aorta is commonly spoken of as consisting of the *ascending aorta*, the *arch of the aorta*, the *descending thoracic aorta*, the *abdominal aorta*. The branches arising from the aorta are as follows:

Portion of Aorta	*Branches*
Ascending aorta	Coronary arteries
Arch	Innominate or brachio-cephalic Left common carotid Left subclavian
Descending thoracic	Pericardial Bronchial Esophageal Posterior mediastinal Intercostal

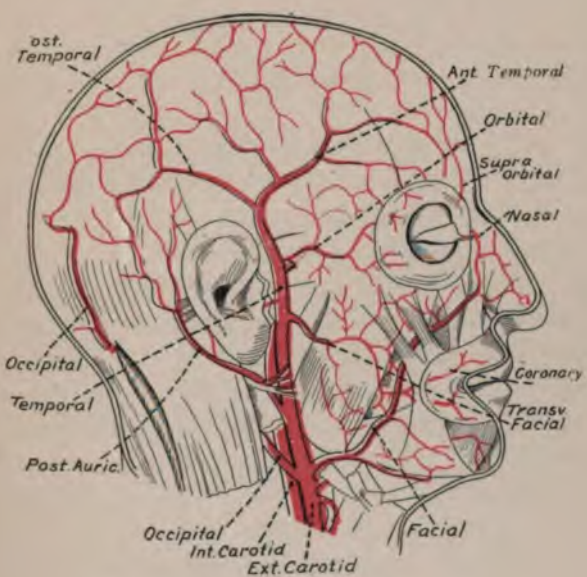

FIG. 96.—Superficial arteries of the head.

Abdominal aorta	Celiac axis
	Inferior phrenic
	Superior mesenteric
	Inferior mesenteric
	Middle suprarenal
	Renal
	Spermatic in male, ovarian in female
	Lumbar
	Dorsal
	Middle sacral

541. THE CORONARY ARTERIES.—The right and the left coronary arteries arise from the aorta immediately above the margin of the semilunar valves. They anastomose with each other and encircle the heart, giving off numerous small branches for the supply of the heart's substance.

542. THE INNOMINATE ARTERY.—The innominate, known also as the *brachio*[1]*-cephalic artery*, is about one and a half inches in length. It ascends obliquely from the arch of the aorta to the upper edge of the right clavicle, near the articulation of the latter with the sternum. There the innominate divides, forming the right common carotid and right subclavian.

543. CAROTID ARTERIES AND THEIR BRANCHES.—The right common carotid springs from the innominate artery, the left from the arch of the aorta. They ascend, one on either side the trachea, to the upper level of the laryngeal prominence

[1] From the Latin *brachium*—the arm and *cephalicus*—pertaining to the head.

known as *Adam's Apple*, where they divide, each one forming two branches called the *external* and *internal carotids*. The two external carotids give off branches for the supply of the throat, skull, face, ears, and tongue. Two very important branches are the superficial temporal and the facial. Each temporal artery is directly continuous with an external carotid. It commences in the substance of the parotid[1] gland in the interspace between the neck of the condyle of the lower jaw and the external meatus of the ear; it passes up the side of the face in front of the ear, giving off in its course several branches to help supply the parotid gland, ear, and face, and it ends on the forehead a little above the outer angle of the eye, in several branches which anastomose with other arteries, and gives off branches for the supply of the scalp and skull. Each of the two facial arteries arises from an external carotid near the base of the tongue, passes through a submaxillary gland, and curves upward over the border of the lower jaw about one-half inch to the inner side of the angle of the jaw.[2] It then passes up to the outer angle of the mouth and thence to the inner angle of the eye, giving off in its course numerous branches for the supply of the throat and face. The course of this vessel, both in the throat and around the mouth, is very

[1] The parotid and submiliary glands secrete saliva.

[2] Its pulsation can be felt here and especially in etherizing the pulse is often counted at this point.

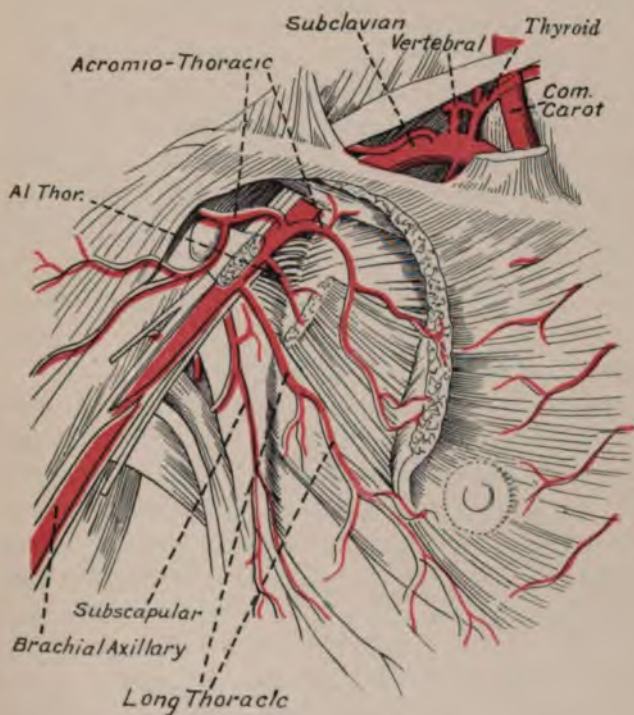

FIG. 97.—Subclavian and axillary arteries.

tortuous—in the former situation to accommodate itself to the movements of the pharynx in deglutition, and in the latter to the movements of the jaw. As can be seen in Fig. 96, the arteries of the face and skull anastomose very freely. Each internal carotid passes upward and outward from its connection with a common carotid to the carotid foramen[1] in the petrous portion of the temporal bone, where it passes inward, pierces the dura mater, and divides into numerous branches for the supply of the brain and eye.

544. Other Source of Brain Blood Supply and Circle of Willis.—In addition to the internal carotids, some parts of the brain are supplied with blood from branches of the basilar[2] artery which is formed at the base of the skull by the union of the two vertebral arteries. Branches of the internal carotids and of the basilar arteries anatomose at the base of the brain forming what is known as the circle of Willis.

545. The Subclavian,[3] Axillary, and Brachial Arteries.—The right subclavian springs from the innominate artery; the left from the arch of the aorta. Each vessel passes upward and outward and then arches downward and outward to the border of the first rib. Thence it passes into the axilla and is known as the axillary

[1] Situated directly in front of the ear at its lower edge.
[2] So called from its situation at the base of the brain.
[3] Under the clavicle.

artery, and thence down the inside of the arm[1] to below the bend of the elbow under the name of the *brachial artery;* there it bifurcates forming the radial and the ulnar arteries. The subclavian artery gives off numerous branches for the supply of the neck, back, and chest. The axillary sends branches to the chest, shoulder, and arm, and the brachial to the muscles, bones, and other tissues of the arm.

546. THE ULNAR AND RADIAL ARTERIES AND THEIR BRANCHES.—These two terminal branches of the brachial artery extend down the arm, the ulnar on the inner and the radial on the outer or thumb side. At the wrist the ulnar terminates in two branches, one of which passes in the form of an arch to the radial side of the hand where it unites with a branch from the radial and so forms what is known as the superficial palmar arch; the second penetrates into the deeper tissues of the hand and anastomoses with a branch from the radial, which forms an arch in the deeper tissues of the hand, called the deep palmar arch. The superficial arch, formed principally by the ulnar, helps supply the tissues of the palm of the hand, and the deep arch, which is formed chiefly by the radial, supplies the back of the hand. The ulnar

[1] A depression in the muscles of the arm can be felt along the inner border of the biceps, about the center of the inner surface of the arm, and by pressing the fingers in deeply at this part from before backward, or by the application of a tourniquet, the brachial artery can be pressed against the humerus, and hemorrhage in the arm or hand can be thus controlled.

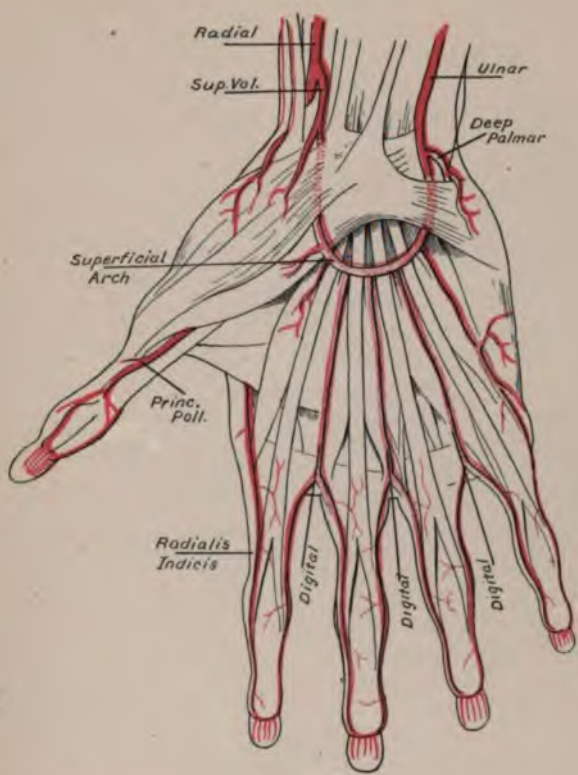

FIG. 98.—Superficial palmar arch and its branches.

and radial arteries both give off numerous branches to supply the tissues of the arms and hand.

547. Arteries Arising from the Thoracic Aorta.—These are the pericardiac, bronchial, esophageal, posterior mediastinal, and the intercostal.

The *pericardial arteries* are vessels of small size which pass to and supply the pericardium.

The *bronchial arteries*, three in number, pass, one to the right and two to the left lung. Branches from these arteries are distributed through the lung tissue to supply it with nutrition, and to the bronchial tubes, esophagus, and pericardium.

The *esophageal arteries*, of which there are five or six, supply the esophagus.

The *posterior mediastinal*[1] *arteries* are small arteries which pass backward to the thoracic vertebra to supply the lymph-nodes in that locality.

The *intercostal arteries*, varying in number from nine to eleven pairs, have their origin from both lateral (side) surfaces of the thoracic aorta. They extend outward to the intercostal spaces and then pass forward in those spaces to the anterior chest wall. They give off branches to supply the muscles and other tissues of chest and back, the mammary gland, the pleura, the spinal cord and its membranes, and the vertebral column.

548. Branches of the Abdominal Aorta.—These, for convenience in description, are divided

[1] Pertaining to the mediastinum, *i. e.*, the central division of the thoracic cavity.

into three groups: the visceral, those which supply the viscera; the parietal, those distributed to the walls of the abdomen; the terminal, the branches formed by the bifurcation of the aorta. The visceral group comprises the celiac[1] axis, the suprarenal, the superior mesenteric, the renal, the spermatic (ovarian), and the inferior mesenteric. The parietal group consists of the phrenic, lumbar, and the middle sacral arteries, and the terminal branches are the right and left common ilia arteries.

The *celiac axis* is a short, stout trunk, about one half-inch in length, which arises from the aorta just below the aortic foramen in the diaphragm. It divides into three arteries called the *gastric*, *hepatic*, and *splenic*.

The *gastric artery* passes to the stomach and gives off branches for the supply of that organ and the esophagus.

The *hepatic artery* extends to the liver, and its branches are distributed to the tissues of that organ and to those of the gall-bladder, omentum,[2] part of the stomach, pancreas, and upper part of the duodenum.

The *splenic artery* passes along the upper surface of the pancreas to the spleen. Its branches are distributed to the pancreas, spleen, and parts of the stomach.

The *superior mesenteric* arises from the aorta

[1] From the Greek *koilos*—hollow.

[2] Described in paragraph 703.

about one-quarter of an inch below the celiac axis. It is distributed to the small intestine, except the part of the duodenum supplied by the hepatic, and to part of the large intestine.

The *inferior mesenteric* is given off from the aorta a little above its bifurcation. It supplies the lower part of the large intestine and, under the name of the hemorrhoidal artery, the rectum.

The *renal arteries* arise from the aorta a little below the superior mesenteric and pass one to each kidney. The nature of the distribution of their branches will be described in connection with the structure of the kidneys.

The *suprarenal arteries*, known also as the adrenal, extend to and supply the suprarenal bodies.

The *spermatic arteries* (in the male) are given off from the front of the aorta. They supply the testes.

The *ovarian arteries* (in the female) take the place of the spermatic arteries of the male. They send branches to the Fallopian tubes, ovaries, and uterus.

The *two phrenic arteries* arise from the aorta, just below the diaphragm, the under surface of which they supply.

The *lumbar arteries*, four or five in number on each side, pass from the sides of the upper portion of the abdominal aorta. Their branches are distributed to the muscles of the back and abdomen, the lumbar vertebra, and the spinal cord.

The *sacra media* arises from the lower end of

the aorta and its branches are distributed to the sacrum and coccyx.

The right and left *common iliac arteries* originate as the result of the bifurcation of the abdominal aorta These two arteries bifurcate in turn, each one giving rise to an internal and external iliac artery.

The branches of the internal iliac arteries are distributed to the pelvic organs, pelvic walls, the external genitals, the buttocks and structures about the hip joint. One very important branch of this artery, in the female, is the uterine artery, the branches of which supply the tissue of the uterus. The course of these vessels in the uterine tissue is very tortuous in order to prevent them being stretched and injured when the uterus enlarges during pregnancy.

The branches of the different arteries supplying any one of the abdominal or pelvic organs anastomose freely with each other; thus, even some of the large branches can be ligated in operation without cutting off the nutrition from the organ.

549. The External Iliac and its Branches. —The two external iliac arteries pass from their bifurcation from the right and left common iliac down through the abdomen, over the brim of the pelvis, down and around the thigh, on the inner side to the lower end of the popliteal space—behind the knee. The portion of the artery extending from the pelvic brim to the upper part of the popliteal space is called the *femoral artery*;

the portion in the back of the knee joint is called the *popliteal artery.* Both the femoral and popliteal arteries give off several branches for the supply of the soft tissues and bones of the thigh and knee joint. The popliteal artery ends by dividing into two arteries called the anterior tibial artery and the posterior tibial artery.

The *anterior tibial artery* passes around from the popliteal space to the front or anterior surface, down which it extends to the ankle; there it receives the name of the dorsalis pedis.[1] It gives off several branches for the supply of the structures in the anterior part of the leg.

The *posterior tibial* extends down the back of the leg on the tibial side to the heel, where it divides into the internal and external plantar arteries. It gives off several branches which supply all the tissues of the leg excepting those in front. One of the largest branches is called the *peroneal.*[2] This branches off from the posterior tibial about half an inch below the bifurcation of the latter from the popliteal, and extends down the outer or fibula side of the leg.

550. The Dorsalis Pedis and Plantar Arches.—The dorsalis pedis is the continuation of the anterior tibial. It extends from the ankle over the dorsum[3] of the foot on the tibial side to

[1] From the Latin *dorsum* or *dorsalis*—the back and *pedis*—a foot.

[2] From the Greek *perone*—the fibula.

[3] From the Latin *dorsum*—the back.

the great toe. It then passes through the interosseous[1] muscles to the sole of the foot. It gives off branches which help supply the dorsum and sole of the foot and the toes, and help the external and internal plantar arteries form the external and internal plantar arches. These arches give off branches which are distributed to the digital end of the foot and the toes.

The Veins

551. THE PULMONARY VEINS.—The veins belonging to the pulmonary system originate from the capillary network in the air cells of the lungs. The innumerable small veins of each lung unite to form two large veins, and, as such, leave the lung and pass to the left auricle of the heart. They hold *arterial* blood.

The Systemic Veins

552. CLASSIFICATION.—There are a great many more large veins than there are arteries. They have been classified according to their location and nature as *superficial veins*, *deep veins*, and *sinuses*.

553. DISTRIBUTION.—The superficial veins are found between the layers of superficial fascia. They connect with the deep veins by means of branches extending inward. The deep set usually accompany the arteries and are generally enclosed

[1] Between the bones.

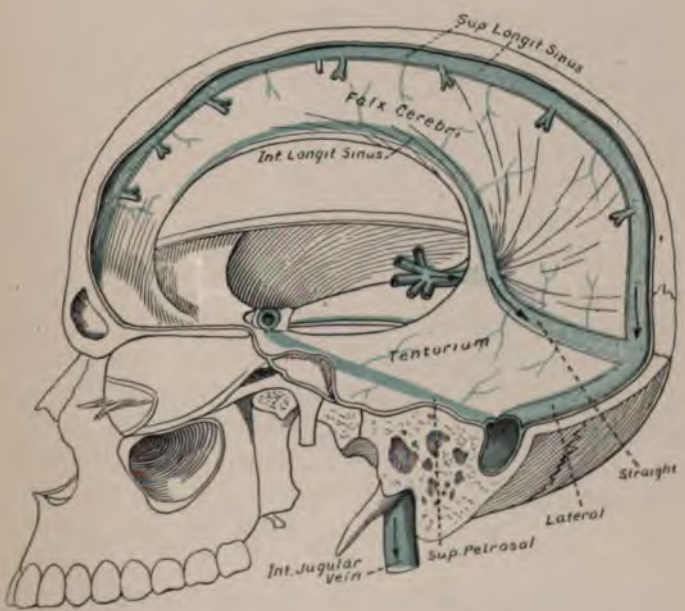

FIG. 99.—Sinuses of the dura, left lateral view.

in the same sheath with those vessels. The smaller of the main arteries, as the brachial, radial, ulnar, tibial, and peroneal are accompanied by two veins, one lying on each side of them. Veins so arranged are called *venæ comites*, *i. e.*, companion veins. The larger of the main arteries as the axillary subclavian, popliteal, and femoral, have usually only one accompanying vein, and in some cases the deep veins do not accompany the arteries; *e. g.*, the veins of the skull and spinal canal and the hepatic veins in the liver. The veins anastomose even more freely than the arteries.

554. SINUSES.—Sinuses are venous channels found in the interior of the skull. They are formed by a separation of the layers of the dura mater, their outer wall consisting of the fibrous coat of that membrane and their inner one of its internal or endothelial layer. This layer is continuous with the walls of the vessels which empty their contents into the sinuses. The location of these sinuses can be seen in Fig. 99.

Names and Location of the More Important Veins

555. THE CORONARY VEINS.—These veins return the blood from the heart substance—the myocardium. They empty directly into the right auricle of the heart, and not, as do the other systemic veins returning blood from the upper part of the body, into the superior vena cava.

556. THE SUPERIOR VENA CAVA AND ITS

TRIBUTARIES.—The superior (known also as the descending) vena cava, is a short trunk varying from two and a half to three inches in length and formed by the union of the right and left brachio-cephalic or innominate veins, behind the lower part of the junction of the first right costal cartilage with the sternum. From this point it extends downward and opens into the right auricle. It receives the blood returning from the head, neck, upper extremities, and thoracic walls.

557. THE RIGHT AND LEFT BRACHIO-CEPHALIC[1] OR INNOMINATE[1] VEINS.—The right innominate vein is about an inch and a half in length, and the left two and a half to three inches. They are formed by the union of the subclavian and internal jugular veins, behind the sternum end of each clavicle, and descend to just below the cartilage of the first rib, close to the right border of the sternum, where they unite to form the superior vena cava.

558. THE INTERNAL JUGULAR VEINS.—These veins receive the blood from the numerous veins and the sinuses of the cranial cavity. They commence in the base of the skull and descend, one on either side, through the neck on the outer side of, first, the internal, and then the common carotids to behind the sternal end of the clavicle where they unite with the subclavians to form the brachio-cephalic veins.

[1] There is only one innominate or brachio-cephalic artery, but two veins.

559. External Jugular Veins.—These two veins receive the blood from the face and exterior of the cranium. They commence, one on either side of the neck, in the substance of the parotid glands, on a level with the angles of the lower jaw, being formed by the union of two of the larger veins of the face. They terminate in the subclavian veins, opposite the middle of the clavicles.

560. Veins of the Upper Extremities.—The deep veins are the venæ comites (companion veins) which accompany the arteries of the forearm and arm, the axillary and the subclavian vein; the last two follow pretty much the same course as the arteries of the same name. The principal superficial veins are (1) the *radial*, which communicates in the hand with the deep palmar arch and runs up the radial side of the forearm to a little above the bend of the elbow where it joins the median cephalic vein; (2) the *posterior ulnar*, which runs up the dorsal aspect of the ulnar side of the forearm; (3) the *anterior ulnar* which extends up the front surface; (4) the *common ulnar*, formed by the union of the posterior and anterior, which after a short course joins the median basilic; (5) the *median*, extending along the front of the arm, from the wrist to the bend of the elbow, where it bifurcates, forming (6) the *median basilic* and (7) the *median cephalic* veins. The first of these, the median basilic,[1] which is

[1] This is the vein commonly chosen when performing phlebotomy, intravenous infusion, etc.

the larger of the two, runs upward to about the center of the arm where it joins the common ulnar to form (8) the *basilic*. The median cephalic runs a short course upward and joins the radial to form (9) the *cephalic*. The basilic vein as it approaches the axilla unites with the inner vena comes[1] of the brachial artery to form the axillary vein. The cephalic ascends the arm and ends in the axillary vein.

561. VEINS OF THE THORAX.—The majority of the principal veins of the thoracic walls, the spinal canal and cord, the abdominal and pelvic walls and viscera bear the same name and follow the same course as the arteries. Some exceptions are:

562. *The Inferior Vena Cava.*—This large trunk vein which receives and carries to the heart the blood from the lower extremities, the pelvis, and the greater part of that from the abdomen, is formed by the union of the two common iliac veins at a level with the fifth lumbar vertebra. It extends upward through the abdomen and pierces the diaphragm near the aorta, enters the pericardium, and opens into the lower and back part of the right auricle.

563. *The Azygos Veins.*—These are three veins called the right or great azygos vein, the left lower azygos, and the left upper azygos. The great azygos commences in the abdomen as an upward continuation of the lumbar vein, which

[1] Singular of venæ comites.

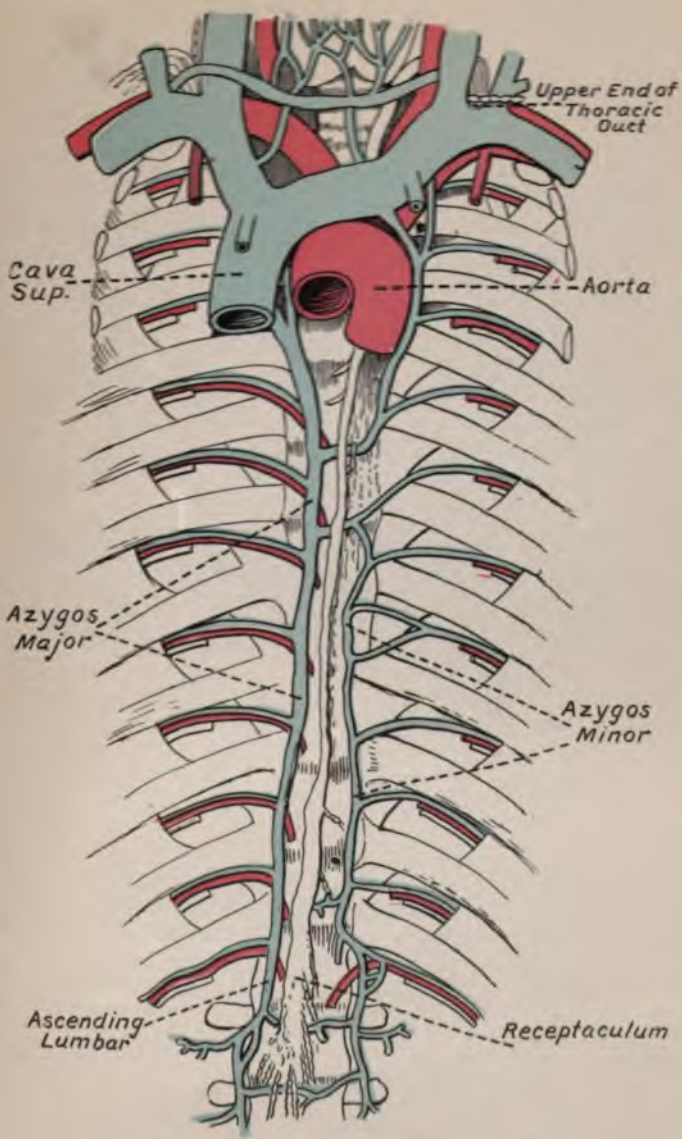

FIG. 100.—Azygos and intercostal veins.

communicates with the common iliac vein and frequently with the inferior vena cava. It ascends on the right side of the vertebral column through the abdominal and thoracic cavities to the level of the fourth thoracic vertebra, where it empties into the superior vena cava. The lower left azygos commences on the left side of the abdomen in the same manner as the right. It ascends on the left side of the vertebral column and connects with the right azygos at about the level of the eighth thoracic vertebra. The left upper azygos branches from one of the large intercostal veins and opens into the left lower azygos. These veins receive the venous blood from the greater part of the dorsal and lateral thoracic walls. They are often called the *supplementary channel* because by virtue of their anastomoses with the common iliac and the superior vena cava they could, if an obstruction occurred in the inferior vena cava, return the blood from the lower part of the body.

564. The Portal Vein—Portal System.—The portal vein has its origin behind the pancreas and in front of the inferior vena cava, on a level with the first lumbar vertebra. It is formed by the junction of the splenic and superior mesenteric veins and receives branches from the stomach and pancreas. It extends upward and to the right for about three inches and enters the liver where it divides into smaller veins which end in plexuses of capillaries. These unite, and with the capillaries arising from the hepatic artery (which

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supply the substance of the liver with nutrient material) they form the hepatic vein through which the blood from the liver reaches the inferior vena cava. The two veins from which the portal vein originates carry the blood from the small intestine and spleen, and those connecting with it carry the blood from the stomach, pancreas, and gall-bladder. Therefore, the portal vein serves to carry the blood from those organs to the liver where it undergoes certain necessary chemical changes before flowing onward through the hepatic vein to enter the inferior vena cava.

565. THE PRINCIPAL VEINS OF THE LOWER EXTREMITY.—The principal deep veins returning the blood from the lower extremities are: below the knee, the venæ comites accompanying the arteries; behind the knee, the popliteal; in the thigh, the femoral. The principal superficial ones are: the internal or long saphenous and the external or short saphenous. The internal saphenous vein arises from the inner side of the plexus of veins situated on the dorsum and instep of the foot called the dorsal plexus, and, ascending the inner aspect of the leg and thigh, ends in the femoral vein about an inch and a half below where the latter passes over the pubic bone and becomes the external iliac vein. The external saphenous arises at the outer side of the dorsal plexus, passes up the back of the leg, and terminates in the popliteal vein.

CHAPTER XIV

THE VASCULAR SYSTEM—*Continued*

Course Followed by the Blood in its Circulation through the Body. Nature of the Heart Action. Meaning of Systole, Diastole, and Cardiac Cycle. Relative Time Required for the Systole and Diastole of the Auricles and of the Ventricles. Heart Sounds and Murmurs. Cause of the Heartbeat. Function of Na, Ca, and K in Connection with the Heart Action and Osmotic Pressure. Influence of the Vagi and the Sympathetic Nerves on the Heart Action. Factors Maintaining Arterial and Venous Circulation. Velocity of the Circulation. Blood Pressure: Nature, Average Degree in Health, Causes of Changes, Means of Ascertaining Degree of Pressure. The Pulse: Cause of Pulsation, Locations Where Felt, What Can Be Determined by Palpitation, Normal Frequency. Lymph: Forces Controlling Circulation. Cause of Edema.

566. COURSE FOLLOWED BY THE BLOOD IN ITS CIRCULATION THROUGH THE BODY.—As has been already stated, the blood flows from the auricles of the heart into the ventricles, from the right ventricle into the pulmonary artery, and from the left ventricle into the aorta. From the pulmonary artery the blood passes to the right and left pulmonary arteries and through these to the innumerable capillaries surrounding the air sacs or alveoli of the lungs, from these into the pulmonary veins, and thence back to the heart, but to the left

instead of the right auricle. The blood forced into the aorta passes to the many branches and sub-branches of this great trunk and thus reaches the capillaries and thereby, practically, all the tissues of the body, both the skeletal and the visceral. From the capillaries it enters the small veins and then the blood in the upper part of the body, except that in the myocardium, goes by way of the superior vena cava to the right auricle of the heart. That from the myocardium reaches the same destination by way of the coronary veins, and that from the abdominal and pelvic cavities, their organs, and the lower extremities, reaches it *via* the inferior vena cava. The blood is kept flowing in the right direction by the valves which are placed wherever their presence is necessary to prevent regurgitation of the blood. Their locations were given in the preceding chapter.

567. NATURE OF THE HEART ACTION.—At the moment that the ventricles eject the blood from their cavities they are in a state of contraction; the tricuspid and the bicuspid valves are closed, and the blood is flowing into the emptied auricles. This condition lasts but the fraction of a second, then the ventricles relax, and as soon as this happens the pressure of blood in the auricles causes the auriculo-ventricular valves to open and the blood from the large veins pours into both the auricles and the ventricles—the heart during this time being in a passive state or at rest, the auriculo-ventricular valves open, but the semi-

lunar valves of the pulmonary artery closed. The auricles being partially filled before the blood begins to flow into the ventricles, and holding rather less than the latter,[1] very shortly become distended; then the large veins contract and a sharp wave of contraction passes first over the auricles and then the ventricles. The contraction of the auricles forces their contents into the ventricles, and the auricles then relax. The ventricles dilate very rapidly on receiving the blood from the auricles and the auriculo-ventricular valves are floated up and closed. The ventricles then contract and at the same time the semilunar valves are forced open and the blood propelled into the pulmonary artery and aorta. The contraction of the ventricles is followed by their sudden relaxation and the blood attempts to regurgitate, but as it does so it pushes up the flaps of the semilunar valves which slap together shutting off the two arteries from the heart. Then follows the pause described at the beginning of this paragraph, in which both the auricles and the ventricles are relaxed and inactive, and the blood is poured into the chambers. The auricles, it will be remembered, relaxed as soon as they had emptied their contents

[1] During life each ventricle is capable of containing about four ounces of blood. The auricles are a little less capacious, but owing to the much thicker walls of the ventricles the difference in the capacity of the chambers is not as great as might be expected from a casual examination of a heart. The walls of the left ventricle are thicker than those of the right, because it has to start the blood on a longer journey than the right.

into the ventricles, and immediately upon their relaxation the blood from the veins poured in; thus the flow from the veins is only retarded for the exceedingly short space of time that the auricles are in contraction.

568. Meaning of Systole, Diastole, and Cardiac Cycle.—The contraction of any part of the heart is spoken of as its *systole;* its relaxation and period of rest as its *diastole.* The period of rest is now often considered separately as the *diastasis* or *pause.* This entire series of events is known as a *cardiac cycle* and it represents a single heart beat.

569. The length of time that the heart takes to complete a cycle depends upon the rate at which it is working. When the pulse-beat is 75 per minute, the time required will be about 0.8 of a second, and the time occupied by each part of the cycle will be about as follows:

Auricular systole	0.1 of a second
Auricular diastole	0.7 of a second
Ventricular systole	0.3 of a second
Ventricular diastole	0.5 of a second
Diastase 0.2 to 0.3 of the diastole	

Thus, there is just 0.4 of a second during each cycle in which the whole heart is in diastole and only 0.1 to 0.2 of a second in which it is at actual rest. It is during this time that the coronary arteries, which supply the heart's substance with blood and, consequently, with food and oxygen, become filled. It is more especially the time of

diastase that is shortened when the heart's action is accelerated, and thus, if the shortening is too great, the heart will fail for lack of rest and nourishment.

570. Heart Sounds and Murmurs.—If the ear is placed over the region of the heart two sounds will be heard with every beat of that organ. These sounds are usually described by the syllables lŭbb-dŭb. The first sound, which is dull and comparatively prolonged, is thought to be due to the vibrations caused by the closure of the auriculo-ventricular valves and the contraction of the ventricles; the second, which is short and sharp, is attributed to vibrations set up by the sudden closure of the semilunar valves. Changes in the nature of these sounds occur in certain diseased conditions of the heart, due very often to failure of the valves to close properly and consequent regurgitation of the blood. Such sounds are called *murmurs*.

571. Cause of the Heartbeat.—Though the cause of the heartbeat has been the subject of inquiry from very early times, it is still but imperfectly understood. Formerly it was thought to be dependent upon stimulation from the central nervous system, but it has been demonstrated by numerous experiments that, though the central and sympathetic nervous systems help to regulate the heartbeat, the actual action of the heart is not dependent upon stimulation from outside nerves; for the heart will continue to beat after connection with the nervous system is severed;

in fact, it has been found that a frog's heart will continue to do so for hours after removal from the body, if its substance is kept moist with what is known as *Dr. Ringer's solution*, which contains small amounts of chlorides of sodium, potassium, and calcium. Thus, the present theory is that the heart muscle possesses some inherent property by means of which its rhythmical contractions are maintained as the result of some internal stimulus. This property seems to be most highly developed in the area of the wall of the right auricle between the openings of the two venæ cavæ, for contractions seem to start there. Contractions are more marked in the auricles than in the ventricles and pass to the latter from their starting point over a bundle of muscle fibers known as the *bundle* of *His*.

572. The nature of the stimulus which maintains the heart's action is still imperfectly understood, but sodium, potassium, and calcium salts are essential factors. There is still considerable difference of opinion regarding the action of the salts, but it has been found that sodium salts are necessary for the irritability of cardiac muscle, but that if present alone they promote relaxation, and that calcium salts, if present in quantities above normal, produce a state of tonic contraction, but when present in normal proportion with the other salts they simply antagonize the action of the latter.

573. INFLUENCE OF THE VAGI AND THE SYMPATHETIC NERVES ON THE HEART ACTION.—Though the activity of the heart is maintained by an internal stimulus, its rate is regulated by fibers from the vagi nerves and fibers from the sympathetic system. It has been found by experiments on anesthetized animals that if the vagi are cut the speed of the heart is accelerated. This and various other experiments have led to the decision that the vagi inhibit the rate of the heart action and the sympathetic nerve supply accelerates it. Both the accelerator and the inhibitory centers are in a state of constant slight activity; therefore under normal conditions the heart muscle is kept in a state of tone and is constantly under the influence of the two antagonistic forces. This enables it to respond quickly to reflex impulses. Unusual stimulation of the vagi may cause marked slowing of the heart rate, and either depression of the vagi or stimulation of the sympathetic or accelerator nerve supply may cause acceleration of the heart action. Such stimulation or depression may be caused by various things; for example:(1) abnormal substances in the blood, such as the toxins produced in disease; (2) drugs, certain of which stimulate the vagi while others depress them, some drugs acting on the origin of these nerves in the medulla, and others on their endings in the heart muscle; (3) injury or disease of the parts of the brain in which the vagi have their origin is

likely to stimulate these centers and cause slowing of the heart rate; (4) reflex action, *e. g.*, some of the abdominal organs get part of their nerve supply, both sensory and motor, from the vagi, and injury or disease of such an organ may, by stimulating the sensory nerve endings therein, send impulses to the vagi centers; thus a blow on the abdomen may cause very alarming slowing of the heart. Also, the sympathetic nerve supply may be stimulated reflexly; common examples are: the acceleration of the heart rate as the result of fear or other emotional disturbances, or by the stimulation of the sensory nerves of the limbs as the result of exercise, etc.

574. FACTORS MAINTAINING ARTERIAL CIRCULATION.—The three most important factors in maintaining arterial circulation are, the pumping action of the heart, the elasticity of the arterial walls, and the resistance offered to the flow of blood by the arterioles and capillaries on account of their small diameter. Also, it is assisted by muscular contractions and by the movements of respiration, but the arterial flow is not nearly as dependent upon these last two forces as is the venous.

575. FACTORS MAINTAINING VENOUS CIRCULATION.—The pumping action of the heart has much less effect upon the venous than upon the arterial circulation, owing to the small caliber and frequent branching of the capillary vessels dividing the arteries and veins; therefore, the blood

flowing through the veins, especially in parts below the heart where it must flow uphill, is dependent upon other influences to keep it in circulation. Some of the more important of these influences are: (1) the suction action of the heart caused by the emptying of the auricles; (2) the respiratory movements which are continually altering the pressure relations in the thorax and abdomen; (3) the pressure of the muscles, both skeletal and visceral, upon the vessels—the greater the amount of muscular contraction taking place the greater the degree of pressure upon the vessels; this is one reason why bodily exercise improves the circulation of the blood; (4) the valves in the veins, which keep the blood flowing in the right direction, *i. e.*, toward the heart.

576. Velocity of the Circulation.—It has been estimated, as the result of numerous experiments,[1] that under normal conditions it takes the portion of blood pumped from the heart by a ventricular contraction about twenty-three seconds to complete its circulation through the system; this would correspond to about twenty-six or twenty-eight beats of the heart.

577. Difference of the Rate of Flow in the Various Vessels.—The rate at which the blood flows varies in the different sets of vessels

[1] Many of these experiments are described in *Text-Book of Physiology*, Howell, page 253, W. B. Saunders & Co., and *Handbook of Physiology*, Kirk, pages 237–240, Wm. Wood & Co.

and also in different sized vessels of the same set. The speed is greatest in the large arteries and least in the capillaries. In the veins the flow is quicker than in the capillaries, but slower than in the arteries.

578. Variations in the Quantity of Blood in Different Parts of the Body.—Activity of any part of the body causes a greater amount of blood to flow to that part and, as the quantity of blood in the body is always about the same, an influx to one part will deplete the quantity in another; *e. g.*, after a hearty meal there will be an increased supply of blood in the stomach and intestines and less in the brain, but violent exercise or a warm bath will increase the amount of blood in the superficial parts of the body and lessen that in the stomach and intestines.

Blood Pressure

579. Difference in Degree of Pressure in Different Vessels.—The degree of pressure exercised by the blood on the walls of the blood-vessels varies, as does the speed at which it flows through the vessels, according to the nature and size of the vessels; thus, it is greatest in the largest arteries and least in the capillaries. The proof of this is seen when a blood-vessel is punctured: if the vessel be an artery the blood is ejected with great force, and the larger the vessel the greater the force and the higher the stream is

projected. The spurt from a vein is not nearly so forceful, and the smaller the vein the less forceful the spurt. Another difference between arterial and venous or capillary flow is that the blood from an artery is projected in spurts, each spurt corresponding to the contraction of the ventricles, and the flow of blood from veins and capillaries is steady and continuous. The reason for this difference can be seen in paragraph 575.

580. Why the Blood Exercises Pressure on the Walls of the Arteries.—The reasons that the blood exercises so much pressure upon the walls of the arteries are: (1) the heart at each systole forces four to six ounces of blood into the arteries; (2) the arteries are full of blood when they receive the extra supply from the heart, because there is not sufficient time between the heartbeats for the blood to pass into the capillaries; (3) the arteries, being capable of considerable distention, dilate to accommodate themselves to the extra supply of blood forced into them; (4) the resistance offered to the flow of blood by the arterioles, capillaries, and small veins.

581. Normal Degree of Blood-Pressure and Causes of Variation.—The pressure exerted by the blood on the walls of the arteries varies with the systole and diastole of the heart, being of course greater during systole and less during diastole. Thus, in adults of from twenty to thirty-five years the average normal pressure exerted by the blood on the walls of the brachial

artery is, during systole, about 110 *mms.* to 120 *mms.*, and, during diastole, 75 *mms.* to 85 *mms.*[1] Pressure varies with age, being less in the young and greater in old age when the arteries have lost much of their elasticity. Pressure is, however, not constantly the same in any individual even in health, for factors that increase the force of the heartbeat increase the degree of pressure. Also, certain drugs, as adrenalin, by causing constriction of the arteries will raise the blood-pressure. Others, as nitroglycerine, by causing dilation of the arteries will lower the blood-pressure. In diseases characterized by over-constricted or sclerotic arteries the blood-pressure may be very high. On the contrary, when arteries have lost their normal tone,[2] as in shock, or when the heartbeat loses its force, the blood-pressure is very low. Two important causes for loss of force of the heartbeat are loss of normal muscular tone and continued high speed of the heart action.

582. Means of Ascertaining the Degree of Blood-Pressure.—Some idea of the degree of blood-pressure can be gained by holding the fingers over those parts of the body where a large

[1] See end of following paragraph.

[2] The muscular walls of the arteries are normally in the same state of slight contraction or tone as the skeletal muscles, and for the same reason. This tonicity of the arteries is very important to the proper functioning of the heart, as, in order to contract properly it needs the slight resistance offered by the contracted vessels. An abnormal degree of contraction, however, compels the heart to work too hard.

artery approaches the surface and in which its pulsation can be felt. If the pulsation feels tense and hard to compress it is known that the blood-pressure is high. If, on the other hand, the pulsation can be easily obliterated by pressure of the fingers, the blood-pressure is low. The knowledge

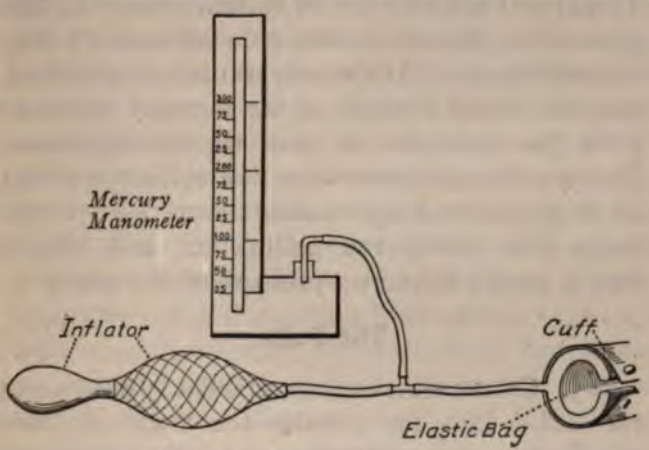

FIG. 101.—Sphygmomanometer.

gained in this way is, however, very indefinite, and several forms of apparatus have been devised of late years by different doctors by which a much more accurate knowledge can be obtained by means of an apparatus called a sphygmomanometer. Of these there are many varieties, but they have the same essential parts, viz: (1) an elastic bag (see Fig. 101) outside of which is a leather cuff; (2) a mercury manometer which is connected with the elastic bag by means of rubber tubing and also

with (3) an air-pump. The way in which this works is as follows: The elastic bag, covered with the cuff, is strapped around the arm and then inflated by means of the pump until no pulsation can be felt in the radial artery at the wrist. The height at which the mercury stands is then read. This gives the maximum or systolic pressure. The pressure on the arm is then reduced until the widest oscillations of the mercury column are obtained, and the lowest position of the mercury meniscus gives the minimum or diastolic blood-pressure. The systolic pressure—when the subject is about 30 or 35 years of age—raises the mercury in the manometer about 120 millimeters, and this is why it is said to exert a pressure of 120 *mms.*

The Pulse

583. CAUSE.—As each ventricular systole forces the blood into the arteries the walls of these vessels expand in order to accommodate the extra supply of fluid, and as the blood passes into the capillaries the arterial walls gradually recoil. This intermittent distention of the arterial walls can be felt on palpation wherever a large artery approaches the surface, and is known as the pulse.

584. LOCATIONS WHERE THE PULSE IS MOST EASILY FELT.—These are: the radial artery on the thumb side of the wrist; the facial artery where it passes over the lower jawbone (see Fig. 96); the temporal artery a little above and to the outer side of the outer angle of the eye (see Fig. 96);

the femoral artery where it passes over the pelvic bone (see Fig. 92); the dorsalis pedis on the dorsum of the foot (see Fig. 92).

585. What Can be Determined by Feeling the Pulse.—By placing her fingers over one of the locations mentioned in the preceding paragraph, a nurse can determine (1) the frequency of the pulse, and, therefore, the frequency of the heartbeat; (2) the force of the heart action—whether strong or weak; (3) whether the pulsation is regular in frequency, *i. e.*, the same number of beats each minute, and force, *i. e.*, each pulsation having the same force, and not some strong and some weaker; (4) the strength of the blood-pressure—how this can be told has been already described; (5) if the pulse is intermittent—*i. e.*, if a beat is dropped; when this happens it means that a heartbeat is so weak that its impulse fails to distend the more distant arteries; (6) if the pulse is dicrotic—*i. e.*, if some pulsations are divided, the second part of the beat being weaker than the first. A dicrotic pulse occurs when there is a lack of tone in the arterial walls, in consequence of which the aorta becomes over-distended during systole, when the blood is injected into it, but, as systole ends, the aorta tends to recover itself and contract, and drives the blood back against the semilunar valves, closing them, but, on account of the suddenness of its contraction, giving rise to a wave—the dicrotic wave—which passes onward toward the periphery.

586. NORMAL FREQUENCY OF THE PULSE.—The normal number of heartbeats per minute varies considerably with age. The average rate at different ages is as follows:

At birth about				130 to 160	per	minute
During the first	year about			120	"	"
" " second	"	"		110	"	"
" " third	"	"		95	"	"
After the third	"	"		72 to 90	"	"
Adults, women			"	65 to 80	"	"
" men			"	60 to 70	"	"

The rate of the pulse may vary very considerably, however, even in health, *e. g.*, it is more rapid when an individual is in the erect posture than when recumbent, also, its rate is increased somewhat after a meal, and usually very considerably by muscular exercise and excitement.

Lymph

587. FORCES CONTROLLING THE FLOW OF LYMPH INTO THE TISSUES.—The principal factors inducing the flow of blood-plasma—which is the origin of the lymph—from the capillaries into the tissues are: (1) the *pressure* under which the blood is in the capillaries, owing to the very much smaller size of these vessels than the arteries and veins; (2) the force of diffusion,[1] due to differences in the chemical composition of the blood-plasma

[1] Described in Glossary.

in the capillaries and the lymph in the tissues; (3) the difference in the osmotic pressure[1] in the capillaries and the tissues; (4) the permeable nature of the endothelial cells forming the walls of the capillaries.

588. Factors Controlling the Flow of Lymph from the Tissues to the Lymphatic Ducts.—The direction of the circulation of the lymph is from the tissues to the thoracic and right lymphatic ducts. The principal causes for the maintenance of this direction are: (1) There is a greater pressure of lymph in the lymph-spaces than in the lymph-capillaries, and a lower pressure in the large vessels near the ducts than in the smaller vessels, so that there is, as it were, a suction force drawing the lymph onward; (2) the movements of respiration; (3) the contraction of the skeletal and visceral muscles; (4) the action of the heart inasmuch as it affects the venous circulation influences to some extent the flow of the lymph.

589. Causes of Edema.—In health the amount of lymph in the lymph-spaces varies from time to time, and in different parts of the body; all increase in capillary pressure causing a temporary increase in the amount of exudation of plasma into the tissues; but normally this increase is never excessive and soon passes off. In certain diseases, however, there may be a very great accumulation of lymph in the tissues, either in

[1] See Glossary.

restricted areas or throughout the body. Such a condition is known as edema. It may be due to (1) the excessive formation of lymph; (2) to interruption in its circulation. The former is much the more common cause. And it may be due (1) to changes in blood-pressure; (2) changes in the composition of the blood; (3) pathological conditions in the walls of the blood-vessels. The reason and nature of a local excessive exudation of plasma into the tissue, as the result of irritation, were described in paragraph 469.

CHAPTER XV

THE RESPIRATORY ORGANS AND RESPIRATION

Purpose of Respiration. Name, Location, Structure, and Function of Each of the Various Organs Concerned in External Respiration. Nature of External Respiration. Mechanism and Causes of Inspiration and Expiration. Influence of Sensory Nerves and of the Vagi on Respiration. Cause of the First Respiratory Movement. Causes of the Interchange of Gases Taking Place in Respiration. Nature of Internal Respiration. Changes in the Blood Due to Respiration. Normal Rate of Respiration. Terms Used in Describing the Quantity of Air Inhaled and Exhaled in Respiration. Capacity of the Lungs. Forces Causing Movement of Air in the Lungs. Changes in the Air as the Result of Respiration. Bad Effects of Poor Ventilation. Required Amount of Ventilation and Air-Space. Abnormal Types of Respiration. Modified Respiratory Movements.

590. DEFINITION—PURPOSE.—By respiration is meant the different processes by means of which the body obtains oxygen and gets rid of carbon dioxid. Respiration serves: (1) to supply the oxygen necessary for the oxidation which the body needs to provide its heat and the energy required to maintain the mechanism of the body at work; (2) to rid the body of the excess carbon dioxid resulting from this oxidation; (3) to help equalize the temperature of the body; (4) to rid the body of excess water.

591. EXTERNAL AND INTERNAL RESPIRATION. —In order that respiration may accomplish all the purposes mentioned in the preceding paragraph, two distinct processes are necessary, viz.: external and internal respiration. The former process takes place in the lungs and consists in the elimination of some of the carbon-dioxide that the blood has brought from the tissues, and of the absorption of oxygen from the air. Internal respiration, which is taking place unceasingly in the tissues, consists of (1) the diffusion of oxygen from the blood-vessels into the tissues, (2) its union there with substances in and of the tissues and their consequent breaking down into simpler substances, such as carbon-dioxide and water, and (4) the passage of these substances into the blood and lymph-vessels.

Organs Concerned in External Respiration

592. NAMES OF ORGANS.—The organs concerned in external respiration are the nose, mouth, pharynx, larynx, trachea, bronchial tubes, and lungs, with certain of the muscles of the thorax and the diaphragm and, sometimes, the abdominal muscles.

The Nose

593. FUNCTION.—The nose serves several purposes: (1) it is the special organ of the sense of smell; (2) it filters, moistens, and warms air passing through it, and should therefore be the principal

port for the entrance of air to the internal respiratory organs; (3) it helps in phonation and in the sense of taste.

594. Main Divisions.—The nose consists of two parts: an external, which constitutes what is generally known as the nose, and an internal, called the *nasal fossæ*.

595. Structure of the External Nose.—The external nose is composed of a framework of bones and cartilage covered externally with skin and internally with mucous membrane. At the lower end of the vestibules are the two openings known as the *nostrils*, around the inner edge of which are a number of stiff hairs which help to prevent the entrance of foreign substances to the internal respiratory organs.

596. Nasal Fossæ.—The internal portion of the nose is divided into two somewhat triangular-shaped cavities called the *nasal fossæ*. The upper portion of the septum dividing the two cavities is formed by the perpendicular plate of the ethmoid bone, the lower part of the posterior portion, by the vomer, and the anterior, by cartilage. The cavities of the nose are seldom of equal size,[1] because, during childhood, the septum is so pliable that even congestion, such as may result from a cold in the head, may bend it. The fossæ,

[1] It is important to remember the fact when feeding a patient through the nose. If any difficulty is experienced in passing the tube used for the purpose in one nasal cavity, withdraw it and insert it through the other.

at their anterior extremity, are continuous with the anterior nares or nostrils and at their upper end

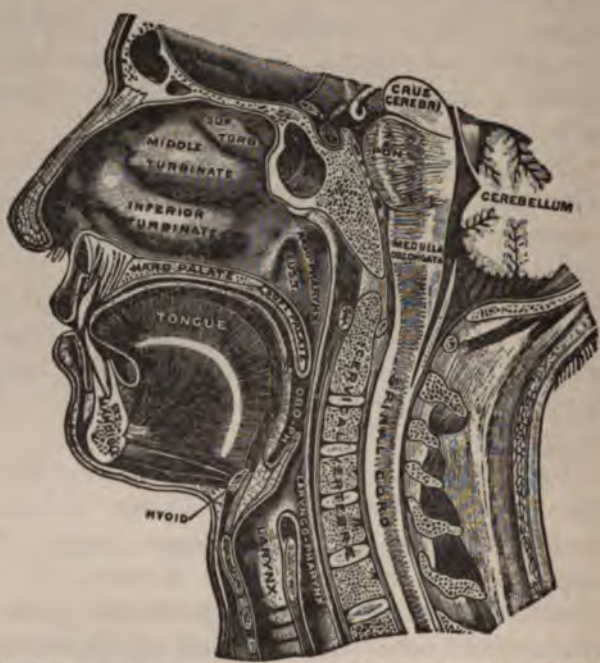

FIG. 102.—Sagittal section of face and neck, showing external wall of right nasal fossa. (Gerrish.)

with the posterior nares which open into the naso-pharynx.

597. WHY IT IS BETTER TO BREATH THROUGH THE NOSE THAN THE MOUTH.—That the nose is a better passageway for the air than the mouth is due to two reasons: (1) the presence

of the hairs inside the nostrils, these acting as filters; (2) the arrangement of the turbinated bones which makes the upper part of the nasal space very narrow and thus forces the air to pass exceedingly slowly over the moist and very vascular mucous membrane, thus moistening and warming it before it gains the internal respiratory organs.

598. PITUITARY MEMBRANE.—The mucous membrane lining the fossæ is called the pituitary[1] membrane from the nature of its secretion, or *Schneiderian* membrane, from Schneider, the anatomist who first showed that the secretion proceeded from this mucous membrane and not, as was formerly supposed, from the brain.

599. NERVE SUPPLY.—The nose gets its nerve supply from the olfactory nerve and from the fifth or trifacial nerve. The olfactory nerve, which is the special nerve for the sense of smell, passes forward from its origin in the brain to the ethmoid bone, where it expands into an oblong mass of gray matter called the *olfactory bulb*. From this bulb are given off numerous nerve filaments which enter the nose through the foramina in the ethmoid bone and are distributed to the mucous membrane covering the ethmoid and the superior and middle turbinated bone. When a person is suffering with a cold in the head the mucous membrane lining the lower portion of the nose becomes congested and so interferes with

[1] From the Latin *pituita*—phlegm.

the passage of odorous substances to the olfactory nerve endings, and thus there is a loss of the sense of smell. The branches derived from the trifacial nerve are distributed to the mucous membrane in the lower part of the nose. These fibers, when stimulated, give rise to such sensations as pain, cold, pressure, etc.

600. COMMUNICATION BETWEEN THE NOSE AND THE FRONTAL SINUSES, ETC.—There are in the bones at the back of the nose openings to minute channels which lead to the frontal sinuses—paragraph 115—and to the antra of highmore—paragraph 127—and inflammatory conditions in the nose frequently extend through the channels into these cavities.

601. THE MOUTH.—As the anatomy of the mouth is more especially adapted to the processes connected with digestion rather than respiration it will be described with the organs of digestion.

602. THE PHARYNX.—Form and Position.—The pharynx forms a part of both the respiratory and digestive systems. It is a musculo-membranous sac, somewhat conical in form, with its base upward and its apex downward. It extends from the under surface of the skull to the esophagus, behind the nose, mouth, and larynx. Its upper portion, which opens into the nose, is called the naso-pharynx. The part seen when looking into the mouth when the tongue is depressed is known as the ora[1]-pharynx, and the lowest portion is known as the laryngo-pharynx.

[1] From the Latin *oro*—to speak.

603. Adenoid Tissue of the Pharynx.—In the mucous membrane of the pharynx there is a considerable amount of adenoid or lymphoid tissue. This sometimes, especially in the nasopharynx, during infancy and childhood, increases to such an extent that it interferes with respiration, and the child is then said to have *adenoids*. Other masses of lymphoid tissue in this part of the body are the tonsils. These will be described in paragraph 691.

604. Apertures of the Pharynx.—There are seven openings in the pharynx, viz.: the two posterior nares communicating with the nose; the two Eustachian[1] tubes leading to the ears; the esophagus, the tube leading from the pharynx to the stomach; the larynx, the tube leading to the bronchi and thence to the lungs; the mouth.

The Larynx

605. Position.—The larynx is situated at the upper and fore end of the neck, between the trachea and the base of the tongue, below and in front of the pharynx.

606. Shape.—At its juncture with the trachea the larynx is narrow and of a cylindrical form, but its upper portion is broader and is shaped something like a triangular box flattened behind and at the sides, but slightly rounded in front.

607. Cartilages of the Larynx.—The lar-

[1] Named after a famous anatomist.

true vocal cords are two bands of mucous membrane, each enclosing a thin elastic band. These are the *false vocal cords*, so called because they are not concerned in the production of the voice.

The Trachea[1]

614. SIZE AND LOCATION.—The trachea, or windpipe, is a straight, flexible tube about four and a half inches in length and three quarters to one inch from side to side. It lies in front of the esophagus and extends from the larynx on a level with the sixth cervical vertebra to opposite the fourth dorsal vertebra, where it divides into two tubes known as the *bronchi*.

615. STRUCTURE.—The trachea is composed of muscular, fibrous, and elastic tissue, stiffened, except at the back, with rounded bands of fibrocartilage and lined with mucous membrane that is covered with ciliated epithelium; the purpose of the ciliated epithelium being to protect the air passages from the entrance of dust and other deleterious substances.

The Bronchi[2]

616. POSITION.—The bronchi are two tubes which branch off on either side from the termination of the trachea. The one on the right side

[1] From the Latin *trachia*—the windpipe. Derived from the Greek *trachys*—rough. So called on account of the marked inequalities felt on its surface.

[2] From the Greek *bronchos*—the windpipe.

goes to the right lung, that on the left to the left lung.

617. Branches of the Bronchi and their Subdivisions.—As soon as a bronchus enters a lung numerous branches are given off. These branches in turn give rise to numerous smaller branches called *bronchioles*. Each bronchiole terminates in small funnel-shaped enlargements known as *infundibula*,[1] and from the outer edge of each infundibulum extend innumerable small finger-shaped sacs called the alveoli[2] or air-cells.

618. Structure of the Bronchi. Like the trachea, the bronchi are constructed of muscular, fibrous, and elastic tissue, stiffened, so that they will remain constantly as rounded, open canals, with bands of fibro-cartilage, and lined with mucous membrane covered with ciliated epithelium.

619. Structure of the Bronchioles, Infundibula, and Alveoli.—The structure of the larger bronchioles is similar to that of the bronchi, but the smaller ones have no fibro-cartilage and less fibrous tissue. The walls of the infundibula are about the same as the smaller bronchioles, but those of the alveoli are composed of an exceedingly thin film of muscular and elastic tissue lined with mucous membrane.

The Lungs

620. Position and Shape.—The lungs are the

[1] Latin *infundibulum*—a funnel (plural *infundibula*.)
[2] Sing., alveolus. Latin, a little trough.

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two large organs which fill the thoracic cavity, except for the space occupied by the air-passages, the heart, the large blood-vessels, lymphatics and esophagus. In shape they resemble cones with concave bases. The bottom or base of each cone rests upon the diaphragm, and the top or apex extends to about an inch above the first rib.

621. STRUCTURE.—The lung substance, which is soft and sponge-like, consists of the bronchioles and their terminations—the infundibula and alveoli—innumerable blood-vessels, lymphatics, and nerves, held together by elastic connective-tissue and covered by a serous coat which is derived from the pleura, as described in paragraph 627.

622. LOBES AND LOBULES.—The substance of the lungs is divided by deep fissures into *lobes*—the right into three and the left into two. The lobes are again divided by smaller depressions into lobules.

623. DIFFERENCE IN THE SIZE OF THE LUNGS.—The right lung is broader and heavier than the left, but it is somewhat shorter on account of the position of the liver, which extends higher in the abdomen than do any of the other abdominal organs. The left lung is not only narrower but is more deeply indented than the right, in order to provide space for the heart, which, it will be remembered, extends much farther to the left than to the right side.

624. THE HILUM.[1]—On the inner surface of

[1] Latin *hilum*—a little thing. The word is used in anatomy to designate a small fissure or depression.

each lung, very near the center, is a depression known as the hilum, through which the bronchus, blood and lymphatic-vessels, and nerves enter and leave the lung.

625. NERVE SUPPLY.—The nerve supply of the substance of the lungs is derived from the sympathetic system and from branches of the tenth cranial nerves known as the pneumogastric or vagi. The part which these nerves take in respiration will be discussed in paragraphs 638 and 639.

626. BLOOD SUPPLY.—Blood is brought to the lungs from the heart through branches of the bronchial and pulmonary arteries. The former contain the blood needed for the nourishment of the heart, and on entering the hilum give off branches, from which capillary extensions go to all parts of the lung substance—the connective tissues, the walls of the blood-vessels, etc. The pulmonary arteries[1] carry from the right ventricle to the lungs the blood which has been through the system, giving up its oxygen and gathering carbon-dioxide. On entering the lungs the pulmonary arteries give off numerous branches which gradually pass into capillaries that form a plexus or network around the infundibula and alveoli. The walls of both the capillaries and the air sacs

[1] It will be remembered that there is but one pulmonary artery opening from the heart, but that about two inches from its origin this artery divides into two branches, one of which goes to the right and the other to the left lung.

being exceedingly thin and of such a nature that gases can readily diffuse through their membrane, an interchange of carbon-dioxide and oxygen readily takes place. The forces which further this diffusion of gases will be considered in connection with the respiration.

The Pleura[1]

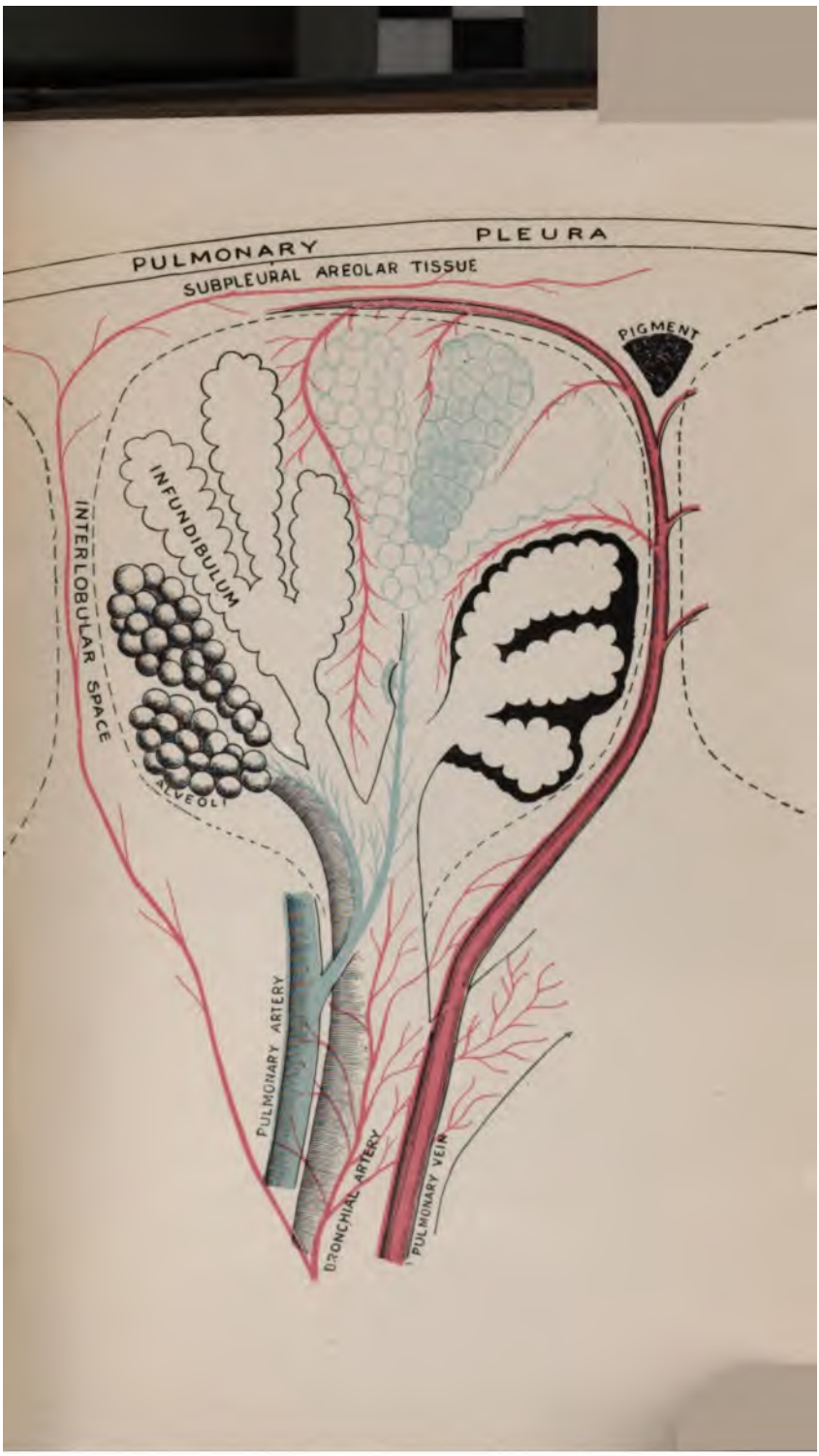
627. NATURE.—Each lung is invested upon its external surface with an exceedingly delicate serous membrane named the pleura, which encloses the organ as far as its root and is then reflected upon the inner surface of the thoracic wall, thus forming a closed sac. The portion of the sac covering the lung is called the visceral layer, and that covering the chest wall is called the parietal layer. The space between the two layers is called the cavity of the pleura. The space, however, is very minute, the lung and the chest wall being almost in contact.

628. FUNCTION.—The function of the pleura is to secrete a lubricating liquid which prevents friction between the lungs and the chest walls during the movements of respiration.

629. PLEURISY.—This is the name given to an inflamed or irritated condition of the pleura which sometimes occurs. There are two types of the disease; in one there is a lack of the lubricating secretion and when, at each inspiration, the two roughened layers of pleura come in contact, great

[1] From the Greek *pleura*—a rib.

FIG. 105.—Diagram of a lobule of the lung. A bronchiole is seen dividing into two branches, one of which runs upward and ends in the lobule. In the lobule are four groups of infundibula. At the left are two infundibula, the alveoli of which present their outer surfaces. Next are three infundibula in vertical section, the alveoli of each opening into the common passageway. Upon the ultimate bronchiole of this group are alveoli. In the next group the first infundibulum shows a pulmonary arteriole surrounding the opening of each alveolus, and the second gives the same with the addition of the close capillary network in the wall of each alveolus. The same arrangement of vessels is seen in the alveolus upon the bronchiole of this group. Around the fourth group is a deep deposit of pigment, such as occurs in old age, and in the lungs of those who inhale coal dust and the like. On the bronchiole lies a branch of the pulmonary arteries (blue), bringing blood to the infundibula for aëration. It also supplies nourishing blood to the tubes and other structures within the lobule. Beginning between the infundibula are the radicles of the pulmonary vein (red), a root of which lies upon the bronchiole. The bronchial artery is shown as a small vessel bringing nutrient blood to the bronchiole (outside of the lobule), the artery and vein, and all of the structures between and around the lobule. No attempt is made to show the sustentacular tissue which occupies the spaces within and around the lobule. (Gerrish.)


PULMONARY PLEURA
SUBPLEURAL AREOLAR TISSUE
PIGMENT
INFUNDIBULUM
INTERLOBULAR SPACE
ALVEOLI
PULMONARY ARTERY
BRONCHIAL ARTERY
PULMONARY VEIN

pain is produced. This type is called *dry pleurisy.* In the second form, known as *pleurisy with effusion,* there is an over-abundant secretion of fluid. There is usually less actual pain with this type of the disease, but it interferes very seriously with respiration.

630. MEDIASTIAL SPACE.—The space left in the median line of the chest by the non-approximation of the two pleuræ is known as the *mediastial space.* It extends from the sternum in front to the spine behind.

External Respiration

631. OF WHAT IT CONSISTS.—External respiration consists of the alternate expansion and contraction of the chest walls and the lungs by means of which air is drawn into and expelled from the lungs. The first action is known as *inspiration;* the second is known as *expiration.*

632. MECHANISM OF INSPIRATION.—During inspiration the diaphragm[1] contracts, its dome becomes flattened and is pulled downward, its sides are drawn away from the chest walls. At the same time the contraction of certain of the muscles of the thorax (see next paragraph) elevates the ribs in front and at the sides; the size of the thorax is thus considerably enlarged, and as the lung substance expands in keeping with the sides and floor

[1] The action of the diaphragm is much more pronounced in men and children than in women. This is thought to be due to a difference in clothing rather than to physiological differences.

of the thorax a vacuum is created in the air-cells, which the outside air is sucked in to fill.

633. Muscles Concerned in Inspiration.—These are the diaphragm, the external intercostals, part of the internal intercostals, the scaleni, the levatore costarum, the muscles of the glottis, and, in hurried or forced breathing, those around the nostrils.

634. Mechanism of Expiration.—In expiration the lungs and the thorax return to the position and size they occupied before the act of inspiration, and air is thus expelled from the lungs. Quiet expiration is an almost passive act, due in part to the elastic recoil of the muscles and tissues involved in inspiration. In forced expiration, however, many of the abdominal muscles are involved. These act (1) by pressing the abdominal viscera against the diaphragm and thereby forcing it up; (2) by drawing down the ribs and costal cartilages.[1]

635. Nature of Respiratory Movements.—Respiration is both a voluntary and an involuntary act; that is to say, it can be controlled to a certain extent by the will, but, except on occasion, it proceeds without any voluntary effort. In fact, any attempt to modify the respiratory rhythm will soon cease from one or other of two causes, viz.: (1) conscious effort will be followed by such a sense of fatigue that it will soon be discontin-

[1] It will be remembered that the abdominal muscles are attached to the ribs and costal cartilages.

ued; (2) continued suppression of respiration will produce an abnormal increase in the amount of carbon-dioxide in the blood, which, by stimulating that part of the medulla oblongata known as the respiratory center, will eventually cause inspiration.

636. Cause of Inspiration.—Unlike the beat of the heart, the respiratory movements are entirely dependent on the nervous system, especially that part known as the *respiratory center*. Anatomically the respiratory center has not been sharply localized further than that it is in the medulla oblongata and below the center which controls the vasomotor system. It is brought into relation with the muscles of respiration by efferent nerves which, arising in the center (1) pass down the cord and end in the gray matter there at the different levels at which the motor nuclei of the respiratory nerves are situated, and (2) which pass on to such of the motor centers of the vagus and facial nerves as are connected with any of the muscles of respiration. The impulses arising in the respiratory centers are thus transmitted to the nerves which cause action in the muscles concerned in the act of inspiration.

637. Causes of the Activity of the Respiratory Center.—Numerous experiments have shown conclusively that the respiratory center, like the heart, works automatically—*i. e.*, the stimuli discharged from it are produced within its own cells—but that it is also very easily affected

by afferent impulses. The stimulus causing the automatic action of the respiratory center is, however, different from that affecting the heart. It has been found that an excess of oxygen in the blood will cause the respiratory center to cease acting, in other words to become *apneic*,[1] and that the same effect will follow the quick removal of carbon-dioxide. Therefore, it is now the generally accepted theory that the usual stimulus activating the respiratory center is the carbon-dioxide which the blood gathers from the tissues in its voyage through the body. This accounts for the increased rate of respiration in fever—the excessive oxidation that is going on when the temperature is high being naturally associated with an increased production of carbon-dioxide.

638. Influence of the Sensory Nerves on the Respiratory Center.—Though the respiratory center works automatically, it is also influenced by sensory nerves passing to and from the brain. This is shown by the changes caused in respiration by any strong stimulation of such nerves, as by sudden pain, strong emotion, cold, etc. Hence one reason for inducing pain in the treatment for opium poisoning, this drug causing death by depression of the respiratory center.

639. Nerves over which Impulses Travel to the Muscles Concerned in Respiration.—The nerves acting as the chief tracts are: branches of the vagi, intercostal nerves, and, to the dia-

[1] From the Greek *apnoia*—want of wind.

phragm, the phrenic. Experiments seem to show that the vagi fibers are of importance in regulating the speed of the respiratory movements. Experiments seem to prove also that the fibers from the vagi which supply the lungs are of two kinds: (1) inspiratory fibers, which tend to increase the rate of respiration, and (2) expiratory fibers, which inhibit the action of the inspiratory set. The inspiratory fibers are stimulated to action by the collapse of the lung, and the expiratory by the expansion of the lung.

640. Causes of Expiration.—It is now thought by many physiologists that the respiratory center would have been more correctly named the *inspiratory center;* normal respiration actually consisting of an active inspiratory act followed by a passive expiratory movement due, as stated in paragraph 634, to the elastic recoil of the muscles engaged in inspiration; and in forced respiration, as in dyspnea, coughing, etc., when expiration does become an active movement, it is not known what activates the nerves supplying the muscles engaged in the action. Some authorities consider that the nerve stimulation comes from the respiratory center as the result of extra stimulation arising in dyspnea, from an excessive amount of carbon-dioxide in the blood, or in coughing, etc., from increased nerve impulses from the sensory nerves. But other physiologists think that the nerve impulses which activate the muscles causing active expiratory movements are derived from

a different center as yet undiscovered—an *expiratory center.*

641. CAUSE OF THE FIRST RESPIRATORY MOVEMENT.—The fetus, during intra-uterine life, receives its necessary supply of oxygen and gives off carbon-dioxide by means of the blood-vessels of the umbilical cord, which connects its circulatory system with that of the mother. Its lungs are therefore unnecessary during that time, and remain in a collapsed condition until the first breath is taken at birth, when the lungs become filled with air and the respiratory center starts the automatic action that continues until death. The causes of the starting of activity are supposed to be: (1) the increased venosity of the blood due to the cutting of the umbilical cord; (2) stimulation from the sensory nerves due to cooler[1] air on the skin, handling, etc.

642. CAUSES OF INTERCHANGE OF GASES THAT TAKES PLACE IN RESPIRATION.—It has been stated repeatedly in the preceding pages that carbon-dioxide passes from the blood and oxygen into the blood while it is flowing through the pulmonary capillaries. The reason the carbon-dioxide leaves the blood is that the latter is passing through a region in which there is less carbon-dioxide than in itself, and the tendency of gases is always to mix in uniform proportion.[2] Following

[1] The child while in utero has been in an atmosphere with a temperature of about 100° F.

[2] See Diffusion of Gases—Glossary.

this same tendency, the oxygen, being present in larger amounts in the air-cells than in the blood, passes from the alveoli into the capillaries.

643. INTERNAL RESPIRATION.—By internal respiration is meant the interchange of gases—oxygen and carbon-dioxide—that takes place between the blood and the tissues, as the blood flows through the capillaries in all parts of the body. The reasons for this interchange are the same as those causing the exchange in the lungs: (1) there is always a larger amount of carbon-dioxide in the tissues than in the blood, because it is constantly being formed in the former as the result of metabolism; (2) there is less oxygen in the tissues than in the blood—in fact, there is practically no free oxygen in the tissues, for on entering them it at once combines with substances therein. Therefore, the carbon-dioxide passes from the tissues to the blood, and the oxygen from the blood to the tissues.

644. CHANGES IN THE BLOOD DUE TO RESPIRATION.—The principal changes that take place in the blood due to respiration are: (1) it gains oxygen; (2) it loses carbon-dioxide; (3) in consequence of these changes, it assumes a redder color; (4) it becomes slightly cooler. The comparative degree of pressure due to carbon-dioxide and oxygen in the alveoli, arterial and venous blood, and the tissues is as follows:

	OXYGEN		CARBON-DIOXIDE	
Alveoli	100	*mms*	35–40	*mms*
Venous Blood...	37.6	"	42.6	"
Arterial Blood..	100	"	35	"
Tissues	0	"	50 to 70	"

645. NORMAL RATE OF RESPIRATION.—The average rate of respiration for a healthy adult is about 18 respirations per minute, but it is quicker in childhood and infancy, and somewhat slower in the aged. It may vary, however, very considerably, even in health, for it becomes accelerated as the result of muscular exercise, etc.—in fact, anything that influences the heart-beat will, ordinarily, have a like effect upon the respirations, and, except in diseased conditions, the ratio of the respiration and heart-beat remains about 1 to 4 or 1 to 5.

Terms Used in Describing the Quantity of Air Breathed and the Capacity of the Lungs

646. TIDAL AIR.—At each inspiration an average-sized man inspires and expires about 500 *c.cm.* (30 cubic inches) of air. This amount of air exchanged is called *breathing* or *tidal air.*

647. COMPLEMENTAL AIR.—By taking a deep inspiration, 1600 *c.cm.* (100 cubic inches) over and above that inhaled in tidal air can be taken into the lungs. This is called *complemental air.*

648. RESERVE AIR.—All the air contained in

the lungs is not expelled with each expiration, and the amount remaining that could be expelled with a forced expiration is called the *reserve air.* The average amount of reserve air in the adult is about 1600 *c.cm.* (100 cubic inches.)

649. Vital Capacity.—The vital capacity or, as it is sometimes termed, the *respiratory capacity* of the lungs constitutes the quantity of air which a person can expel from his lungs after a forcible expiration following the deepest inspiration possible. The average capacity in the adult is about 3500 *c.cm.* (225 cubic inches). The vital capacity is the sum total of the tidal, complemental, and reserve air.

650. Residual Air.—The lungs cannot be completely emptied, even by forcible expiration, and the amount which remains after the reserve air has been expelled is termed *residual air.* The quantity of residual air varies considerably, as it depends upon the size of the chest, but it has been estimated at averaging about 1600 *c.cm.*

651. Forces Causing Movement of Air in the Lungs.—It is not to be understood from the foregoing paragraph that any definite part of air in the lungs is residual air, for the air is being constantly moved in the lungs and therefore in the course of time renewed. The forces which cause the mixing and movement of the air in the lungs are[1]: (1) the alternate expansion and shrinking of the lungs in the movements of respiration;

[1] See Glossary.

(2) the pulsation of the arteries; (3) the convection currents due to the inequalities in temperature between the air in the lungs and the freshly inspired air; (4) the difference in the proportion of carbon-dioxide and oxygen in the inspired air and the residual air.

652. Changes in the Air as the Result of Respiration.—The air as it is taken into the lungs—*inspired air*—consists of nitrogen, oxygen, and carbon-dioxide in the following proportions:

NITROGEN	OXYGEN	CARBON-DIOXIDE
79 per cent.	20.96 per cent.	0.04 per cent.

The comparative proportion of these gases in expired air is:

NITROGEN	OXYGEN	CARBON-DIOXIDE
79 per cent.	16.02 per cent.	4.38 per cent.

Thus the air loses 4.94 volumes of oxygen and gains 4.34 volumes of carbon-dioxide. Other changes in the expired air are an increase of temperature and of moisture, expired air being, regardless of the temperature of the inhaled air, about the temperature of the blood, and almost, if not quite, saturated with moisture. Some authorities consider that there is also some form of toxic matter present in expired air, but this has never been proved.

653. Bad Effects of Poor Ventilation.—The usual consequences of remaining in a badly

ventilated room are a feeling of general discomfort, headache, languor, and a sense of oppression. It is a well-known fact, however, that people can become so accustomed to a lack of fresh air that its absence causes them little discomfort; but they are, nevertheless, affected by it, as is constantly demonstrated by the lack of vitality shown by those who live in poorly ventilated quarters. The exact reason for the ill effects of poor ventilation is not known. Formerly they were thought to be due to the volatile organic matter and CO_2 given off in the respiration, but experiments have tended to prove that in average ill-ventilated buildings there is not sufficient CO_2 to produce poisoning, and that the organic matter, which comes principally from the stomach and particles of food left in the mouth, is not poisonous, and many authorities consider that the ill effects are due to reduction in blood-pressure, on account of dilation of the cutaneous vessels as the result of over-heating, and to lack of oxygen.

654. Amount of Ventilation and Air Space Necessary to Prevent Vitiation of the Air.—In order to prevent the air indoors becoming vitiated two things are necessary: (1) the air must be changed constantly; (2) the size of rooms must be in proportion (*a*) to the number of people who are to inhabit them; (*b*) the quality of the facilities for ventilation; (*c*) the degree of air contamination likely to occur. Calculations based upon the

[1] Described in Chapter XIX.

amount of air taken into the lungs at each inspiration, and the changes caused in it during its stay in those organs, show that each individual requires as a minimum 1000 cubic feet of air space,[1] and this size space is only adequate when there is sufficient ventilation to change the whole air of the room in the course of every twenty minutes. In hospitals, factories, and other places where air is likely to become vitiated more quickly than in dwelling houses, a greater air space should be allowed for each individual. The following table gives the amount of air space required per capita in different institutions, when the air can be completely renewed in the course of every 30 minutes:

Hospitals	*30–50*	*cubic meters*"	[1]
Prisons	*25*	"	"
Factories	*30–50*	"	"
Barracks	*15–25*	"	"
Theaters	*20–25*	"	"
Halls and Assembly Rooms	*15–30*	"	"
Schools	*7.5–10*	"	"
Classrooms for Adults	*12–15*	"	"

Abnormal Types of Respiration

655. Dyspnea.—By dyspnea is meant difficult or labored breathing. The more common causes of the condition are: (1) over-stimulation of sensory nerves, especially those causing pain in the lungs;

[1] *Text-Book of Physiology*, page 648. Howell. W. B. Saunders Co.

(2) an increased venosity of the blood—*i. e.*, an abnormal increase in the per cent. of carbon-dioxide; (3) a marked decrease of oxygen in the blood. Dyspnea, as the result of an increased per cent. of carbon-dioxide and lack of oxygen in the blood, is likely to occur in any condition in which the normal rate of respiration and of the heart-beat is seriously interfered with, and where there is any interference with the passage of air to and from the lungs.

656. CHEYNE-STOKES RESPIRATION.—This form of respiration was so called because of the two doctors who first discovered it. Its actual cause is unknown. It is frequently associated with advanced brain, heart, and kidney diseases, and has been observed in perfectly healthy children during profound sleep. It appears in two forms: In one, the respirations gradually increase in force and frequency up to a certain point and then as gradually decrease until they entirely cease; a short pause then ensues and the respirations begin as before. In the other form, the respirations gradually increase in force and frequency, as in the former case, but they cease suddenly, instead of decreasing gradually. The phenomena may continue for some time and then cease, or it may continue and cause marked dyspnea.

657. EDEMATOUS RESPIRATION.—The so-called edematous respiration or breathing is the result of the infiltration of fluid from the lung capillaries into the air-cells. It is recognized by the moist

rattling sounds—râles—that follow each inspiration. It is a very serious condition, for, unless relieved, asphyxia will follow.

658. ASPHYXIA.—Asphyxia may be produced by any continual interference with the aëration of the blood, either by direct obstruction to the entrance of air to the lungs, or by any condition that prevents a due interchange of gases between the air and the blood. The condition is associated with severe dyspnea, the expiratory efforts become very forced and convulsive, and, unless the condition is relieved, the convulsive movements may become general and be followed by exhaustion and death. The convulsions are the result of stimulation of motor nerves from impulses due to the over-stimulated respiratory center, the stimulation of the respiratory center being the outcome of the extreme venosity of the blood.

659. MODIFIED RESPIRATORY MOVEMENTS.—There are several actions, such as laughing, sobbing, sighing, hiccoughing, coughing, sneezing, speaking, singing, etc., that are classed as *modified respiratory movements* because in their performance some of the same muscles are brought into action as are used in respiration, but further than this they have nothing to do with the process of respiration. The differences in the sounds produced in these actions is largely dependent upon the relative force and rate of inspiration and expiration and the degree of dilatation of the rima glottidis at the time of these actions, thus:

Laughing consists of a series of short and rapid expirations, during which the glottis is open.

Sobbing consists of a series of convulsive inspirations during which the glottis is closed.

Sighing consists of a prolonged inspiration followed by a sudden expiration.

Hiccough resembles sighing, but the inspiration is sudden instead of gradual, and is followed by a spasmodic contraction of the diaphragm which forces the air back toward the rima glottidis while the latter is still closed—hence the peculiar sound. Common causes of it are irritation of the phrenic nerve, or of sensory nerves of the stomach or intestines.

Speaking is a more complicated action than any of those already mentioned. During speaking, the glottis is more or less closed and the vocal cords in a state of tension, so that when there is a voluntary expulsion of air from the lungs by means of the expiratory muscles it forces its way through the glottis and as it does so sets the vocal cords in vibration; this produces sound. Language is made up of the elementary sounds known as vowels and consonants. The difference between the two sets of sounds and of the various sounds belonging to both sets is obtained principally by changing the shape of the resonance cavities[1]—the pharynx,

[1] These cavities are called the resonance cavities because by alteration of their size and shape they pitch out and emphasize certain component parts of the fundamental tones produced in the larynx.

mouth, and nasal passages, and the tongue, lips, and palate. In making consonant sounds the air or voice is more or less obstructed by means of the lips, teeth, tongue, and palate.

Whispering is performed with the glottis partially open and the air passing through so gently that the vocal cords are not set in motion.

Singing resembles speaking in the manner of its production, but it entails more frequent alteration in the shape of the resonance chambers, in the shape of the glottis, and consequently the tension of the vocal cords, and in the force of the expiratory movements which set the cords in vibration.

CHAPTER XVI

THE GLANDS AND SPLEEN

Glands: Their Nature, Function, and Classification. Nature of Secretions. Names of the Secretory Glands. Names of the Ductless Glands and Other Organs Furnishing Internal Secretions. Location and Function of the Thyroid, Parathyroids, Thymus, Suprarenal Capsules, and Pituitary Body. The Function of the Internal Secretion of the Pancreas, Ovaries, Kidneys, Liver. Names of the Excretory Glands. The Spleen: Function, Location and Structure.

660. DEFINITION.—A gland is an organ which has the power of abstracting specific material from

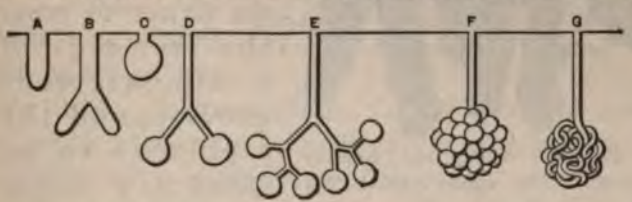


FIG. 106.—Diagram showing development of glands: *A*, a mere dimple in the surface; *B*, enlargement by division; *C*, enlargement by dilatation; *D*, a combination of *B* and *C*; *E*, a racemose gland; *F*, development of method of *E*; *G*, a single tube intricately coiled. (Gerrish.)

the blood flowing through its substance, and, in some cases, of transforming this material into matter of a different nature.

661. CHARACTERISTICS.—Glands vary considerably in their size and structure, some being mere depressions in a membrane or tissue, and others, as the liver, large and complex organs. They all have, however, certain characteristics in common, viz.: they contain secretory cells, a liberal blood supply, and their action is controlled by the nervous system. The usual arrangement of the secretory cells and blood-vessels is for the former to cover the free side of a thin basement membrane and the capillaries to be spread in a dense network upon its under surface. This membrane with its cells and capillaries is found arranged in several different shapes (see Fig. 106), and according to the form it assumes the gland is known as (1) a *simple tubular* or *saccular gland*, or if one end of the tube is coiled, as in the sweat glands (see Fig. 106), a *simple convoluted tubular*

FIG. 107.—Compound tubular gland. The upper part is the duct; the lower is the secreting portion. (Gerrish.)

gland; (2) a compound tubular gland (see Fig. 107); (3) a compound saccular or racemose[1] gland (see Fig. 108).

662. The **simple glands** are formed by a secreting membrane dipping down into the substance beneath it in such a manner as to form innumerable minute tubes, each one having an opening or duct at the free surface. The tubular glands in the stomach and some of those in the intestine are of this type.

FIG. 108.—Compound racemose gland. The resemblance to a bunch of fruit is very marked. (Gerrish.)

663. In a **compound tubular gland** there are a number of branching tubes all opening into one duct. In some glands the free ends of the branching tubes are convoluted; the glands of the kidneys and pancreas are of this type.

664. A **racemose gland** is composed of groups of small sacs which open into a common duct. The salivary glands are examples of this type.

665. DUCTLESS GLANDS.—The glands thus far described all have ducts through which the secretions they manufacture reach the surface of the membrane or the interior of the cavity in which

[1] From the Latin *racemus*—a cluster of grapes.

they are contained. There are, however, some glandular organs in the body which have no such ducts, the secretions they form being taken up by the blood either directly or indirectly by way of the lymphatics—*i. e.*, the secretions are absorbed by the lymphatic vessels in the glands and carried to the superior vena cava.

666. Secretory and Excretory Glands.—It is the office of certain glands to extract material from the blood and change this so that it can be used for special purposes in the body; such glands are called *secretory*[1] *glands*, and the substances they manufacture are called *secretions*. Other glands take from the blood only such matter as is to be discarded or eliminated, and are therefore designated *excretory*[2] *glands*, and the substances they eliminate are called *excretions;* but, in the preparation of most of the excretions, secretion is necessary; therefore the majority of excretory glands are provided with secretory cells. Also, some of the excretions are made use of in the process of their elimination from the body. Thus, the perspiration which is excreted by the sweat glands of the skin helps to regulate the body temperature, and the bile, an excretory product of the liver, helps in the digestion of fats, and is of use in other ways that will be described later. In fact, the bile is of use in so many ways that it is called a secretion as often as an excretion.

[1] From the Latin *se*—aside and *cerno*—separate.
[2] From the Latin *ex*—out and *cerno*—separate.

667. NATURE OF SECRETIONS.—Secretions may be divided into four classes, viz.: (1) Simple secretions, the purpose of which is to lubricate or moisten the surface upon which they are discharged, and which differ very little from the substance extracted from the blood for their manufacture. Of this nature are the secretions of the membranes described in Chapter X, and the secretion of the lachrymal glands; (2) secretions containing substances very different from anything that pre-existed in the blood, among other things one or more organic substances known as ferments or enzymes, which aid in causing the chemical changes that occur in digestion and metabolism; (3) the secretion of the mammary or milk glands, the nature and purpose of which differ from that of all other secretions; (4) the secretions of the ductless glands and of certain other glands and organs which are known as *internal secretions*. Very little is known of the composition of these internal secretions or of the precise nature of their function beyond that they are in some way or other indispensable to metabolism and that certain of them contain chemical substances which produce activity in other organs. These latter substances are named *hormones*.[1]

668. NAMES OF THE SECRETORY GLANDS WHICH FURNISH EXTERNAL SECRETIONS:

The *lachrymal glands*, which secrete the tears for

[1] From the Greek *hormos*—a chain.

the purpose of moistening and keeping the conjunctiva of the eye free from foreign matter.

The *sebaceous glands* of the skin, that secrete an oily substance which lubricates the skin and serves other purposes that will be described in Chapter XXI.

The glands which manufacture the fluids or juices required for the process of digestion, viz.: the *salivary*, *gastric*, and *intestinal glands*, the *pancreas*, and *liver*. These will be described with the organs of digestion.

The *mammary glands*, which after parturition supply milk for the nourishment of the infant.

669. NAMES OF THE DUCTLESS GLANDS AND OF OTHER GLANDS AND ORGANS WHICH FURNISH INTERNAL SECRETIONS.—The principal ductless glands are: the *thyroid*, *parathyroids*, *thymus*, *suprarenal capsules*, and *hypophysis*. The other glands and organs that furnish secretions which reach their destination by way of the blood are: the *pancreas*, *liver*, *kidneys*, and *ovaries*.

670. THE THYROID.—This organ consists of two small oval masses of glandular tissue, situated one on either side of the trachea just below the thyroid cartilage. The two masses, or lobes, are connected at their lower end by a small mass of similar tissue named the isthmus. Little is known of the nature and specific action of the secretion of the thyroid, but if the gland be removed or destroyed a condition known as *myxœdema* results, and the individual's whole system, physical and

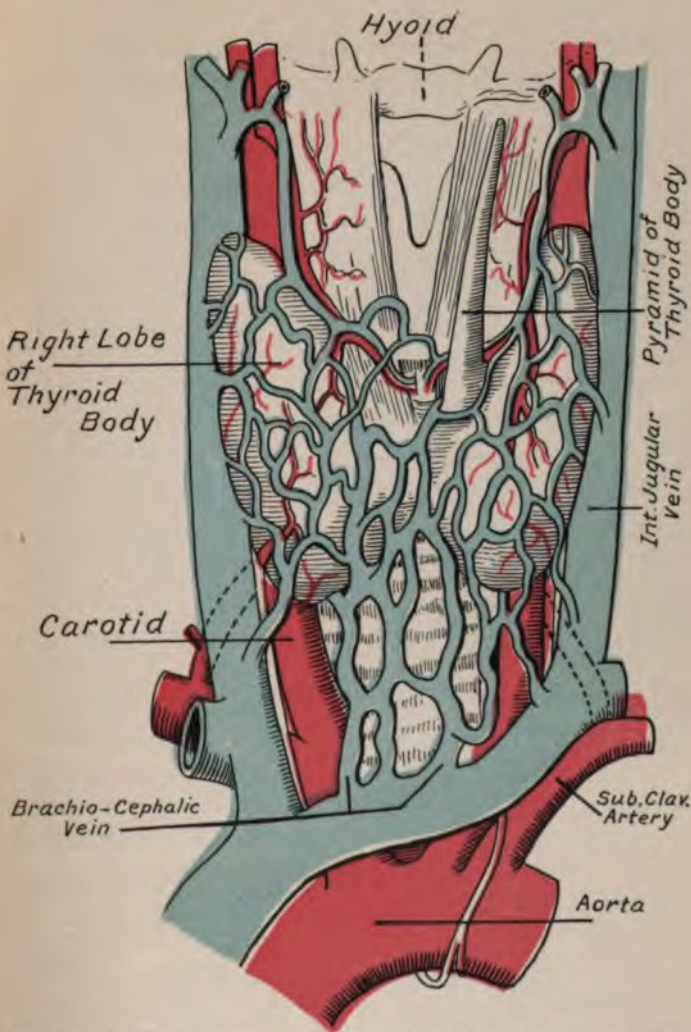


FIG. 109.—Diagram showing the thyroid body and contiguous blood-vessels.

mental, so deteriorates that unless he receives proper treatment he frequently becomes a hopeless idiot. The treatment consists of giving extracts of the thyroid gland of animals. When atrophy or destruction of the thyroid occurs during childhood, growth and mental development are arrested. This condition is known as cretinism. If, on the other hand, the thyroid gland becomes over-active so that there is a superabundant production of thyroid secretion, a condition known as exophthalmic goitre[1] results, prominent symptoms of which are extreme nervousness, accelerated heart action, protrusion of the eyes.

671. In addition to the main thyroid body a number of small masses of thyroid tissue are sometimes found along the trachea as far down as the heart; they are called *accessory thyroids*. Their function is probably the same as the thyroid.

672. THE PARATHYROIDS.—These are small bodies, usually four in number, imbedded in or close to the thyroid. Their function is unknown, but their removal has resulted in defective metabolism, convulsive movements of the skeletal muscles, and, in a few days, death.

673. THE THYMUS.[2]—This is a two-lobed,

[1] This is not the same as the condition known as *goitre*, in which the gland is enlarged. In goitre the secretion is not necessarily interfered with.

[2] From the Greek *thymo*—thyme, so called because the shape of the gland was thought to resemble the flowers of thyme.

elongated glandular body situated below the thyroid. It is called a temporary organ because it is largest during intra-uterine life and infancy, and gradually disappears as body growth ceases. Its function is unknown, but it is thought that the gland may produce a hormon that is in some way concerned with metabolism and the development of the reproductive organs.

674. THE SUPRARENAL CAPSULES OR ADRENAL BODIES.—These are two flat or cocked-hat-shaped bodies which rest one upon either kidney (see Fig. 120). They produce a secretion named *adrenalin*, and *epinephrin*. As the result of many experiments, it is now thought that this secretion has very much the same action in the body as the sympathetic nervous system and that its secretion is stimulated by excitation of this system. Thus, strong excitement, pain, and such emotions as fear and rage, which stimulate the sympathetic system, produce an increased secretion of adrenalin. Some of the pronounced effects of this are: Increased contraction of the arterioles, especially those of the splanchnic area; the driving of blood from the abdominal area into the heart, lungs, central nervous system, and limbs; the inhibition of digestion; increase in the power of the blood to coagulate; relaxation of the smooth muscle of the bronchioles; the liberation of sugar from the liver; lessening of the effects of fatigue. These effects, however, are produced only when the activity of the gland is stimulated. Ordinarily, the

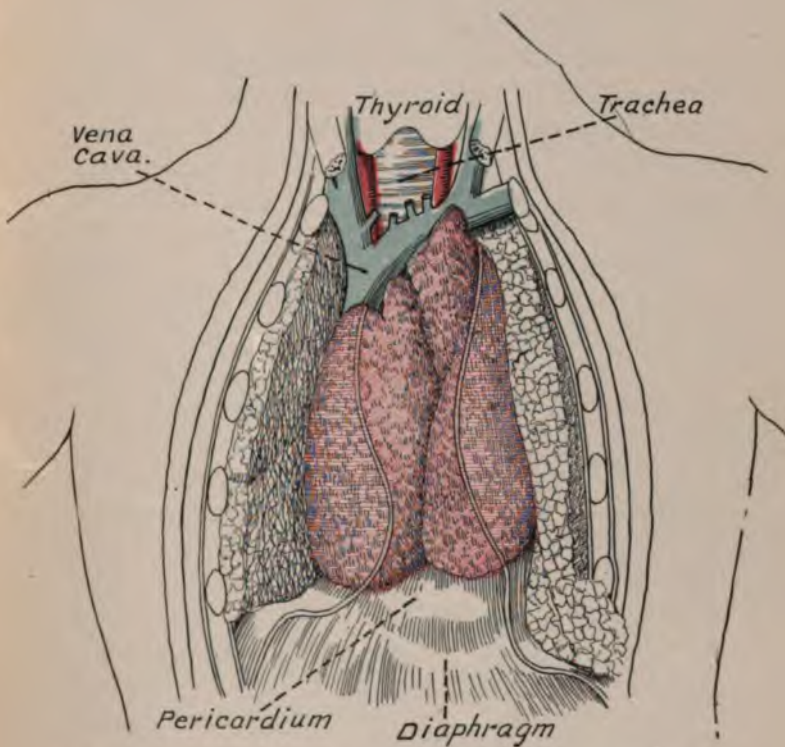


FIG. 110.—The thymus, the sternum and costal cartilages having been removed.

amount of adrenalin secreted is small, but that it is essential for life is shown by the fact that when the glands are diseased—Addison's disease—there is a gradual decline of strength ending in death.

675. The Pituitary Body or Hypophysis.—This is a small, two-lobed body situated in a depression of the sphenoid bone and united to the under surface of the brain by a stalk. Diseases of this gland have shown that it exerts a powerful effect upon growth and metabolism. Hypertrophy leads to a condition known as *acromegaly*, in which the bones of the hands, feet, and face become enlarged, or, if growth has not ceased, a condition known as *gigantism*, in which there is great increase in the growth of all bones. Lack of secretion results in obesity and changes in sexual characteristics. Acromegaly and gigantism are thought to be due to disturbances of the anterior lobe and the other conditions to defects in the posterior lobe. Also, the secretion of this lobe favors the contraction of plain muscle and acts as a galactagogue and diuretic.

676–677. The Internal Secretions of the Pancreas.—In addition to the secretion which the pancreas expels through its duct into the intestine during intestinal digestion, it also secretes an internal secretion that is carried by the blood to the tissues. This secretion seems to be one of the important factors in the oxidation of glucose, diseases of the pancreas which interfere with the

production of this secretion resulting in diabetes mellitus—a disease characterized by a lack of oxidation of glucose in the tissues and its consequent appearance in the urine.

678. INTERNAL SECRETION OF THE OVARIES.—Complete extirpation of the ovaries is followed by a cessation of menstruation, hypertrophy of the uterus, and often by distressing mental conditions, also a faulty metabolism that results in an increase of adipose tissue such as often follows the normal menopause. It has therefore been thought that the ovaries may produce a secretion which is responsible for menstruation and that influences metabolism.

679. INTERNAL SECRETION OF THE KIDNEYS.—It is thought that the kidneys secrete a substance that is of importance to metabolic processes.

680. INTERNAL SECRETION OF THE LIVER.—The glycogen,[1] which is made in the liver from the glucose, brought from the intestines by the portal vein, is by many authorities classed as an internal secretion.

681. NAMES OF THE EXCRETORY GLANDS.—The names of the excretory glands are: the sudoriferous or sweat glands of the skin, the kidneys, and the liver. These glands will be described in other chapters.

The Spleen

The spleen was formerly classed with the duct-

[1] For description of glycogen, see paragraphs 15 and 799.

less glands, but as it apparently furnishes no internal secretion this classification is thought not to be correct.

682. FUNCTIONS.—The functions of the spleen are as yet imperfectly understood, but purposes that have been attributed to it are: (1) that it serves as a location for the formation of leucocytes—the reason for this supposition is that the blood in the splenic vein contains a larger number of white corpuscles than that in the arteries; (2) the formation of red corpuscles during fetal life and for a short time after birth; (3) the preparation of new hemoglobin, or the preservation of the iron set free by the disintegration of red corpuscles, it is thought, may be one of the functions of the spleen, because there is a larger amount of iron present in the spleen than in other parts of the body, except the blood; formerly it was stated that the red cells were destroyed in the spleen, then, this was denied, but it has been shown lately that they are to some extent; (4) it is thought that the spleen may be concerned in the metabolism of absorbed protein food-products—the principal reason for this theory being that uric acid and other waste products of the metabolism of proteins are found therein; (5) it is considered that the spleen may be concerned with digestion or metabolism, in some way as yet unknown, because after a meal the organ gradually enlarges and then as gradually resumes its ordinary size; (6) some physiologists consider that the spleen may

serve to modify the character of abnormal material in the blood, their reason for the supposition being the enlargement of the organ in certain diseases, as malaria and typhoid.

683. SIZE, SHAPE, AND LOCATION.—The spleen is an oblong, bean-shaped body. Normally it measures from six to eight inches in length and weighs about six ounces, but it becomes enlarged in certain diseases, as malaria and typhoid. Usually it resumes its normal size at the termination of the disease, but sometimes it remains permanently enlarged. It is situated directly below the diaphragm, behind the cardiac extremity of the stomach. About the center of its inner concave side is a depression known as the *hilum*, through which the blood and lymphatic vessels and nerves pass to and from the organ.

684. OUTER COAT.—The spleen is covered with a serous coat from which folds pass to the membrane covering the stomach, the peritoneum, kidneys, and diaphragm. These folds help to hold the organ in place.

685. STRUCTURE.—If a spleen is cut open it is seen to consist of a dark red or violet-colored, spongy mass, dotted with numerous white spots. These spots are called the *Malpighian*[1] or *spleen corpuscles*. They consist of a collection of minute bodies resembling the white corpuscles of the blood and are traversed by a capillary network derived from small branches of the splenic artery.

[1] So named from the anatomist who first described them.

The red substance of the spleen is composed of a spongy framework of white fibrous and elastic tissue, the spaces of which are filled with a pulpy mass called *spleen pulp*. This pulp consists of blood thickened by the addition of a large number of leucocytes and of a variety of corpuscles peculiar to the spleen called *splenic cells*.

686. Blood Supply.—The circulation of the blood in the spleen differs from that in any other organ. It receives its supply from the splenic artery, which, just before entering the hilum, divides into several branches. These branches subdivide within the spleen, and, after the usual manner of arteries, the branches grow smaller in size, forming arterioles, but these, instead of merging into capillaries, end abruptly and pour their contents into the spleen pulp. The blood is collected from the pulp by small veins that, by gradually uniting, form the splenic vein, through which the blood flows to the portal vein and thence to the liver.

CHAPTER XVII

THE DIGESTIVE SYSTEM

Names of the Organs of Digestion. Description of the Mouth, Tonsils, Tongue, etc. Location of the Salivary Glands. Location and Structure of the Esophagus. Divisions or Regions of the Abdomen. Nature and Function of the Peritoneum. Purpose, Structure, etc. of the Stomach, Small and Large Intestine, Pancreas, Liver, and Gall Bladder. Collection of Bile.

687. If food is to be of use to the body it must pass into the blood and be carried by it to the tissues. In order for most *organic* food to do this it is necessary for it to undergo certain changes in which the complex molecules of the food material are broken into smaller and simpler molecules and thus rendered of such a nature that they can be absorbed by the blood-vessels and the lacteals. These changes are spoken of as digestion, and the organs in which the food is contained while undergoing these changes, as well as the organs which contribute in other ways to the process, are classed as the digestive system or apparatus.

688. The digestive apparatus thus consists of the alimentary canal and the accessory organs.

The alimentary canal, which extends from the mouth to the opening leading from the rectum—the anus — includes the

Mouth
Pharynx
Esophagus
Stomach
Small intestine
Large intestine

The accessory organs are:

Teeth
Tongue
Salivary glands
Pancreas
Liver and gall bladder

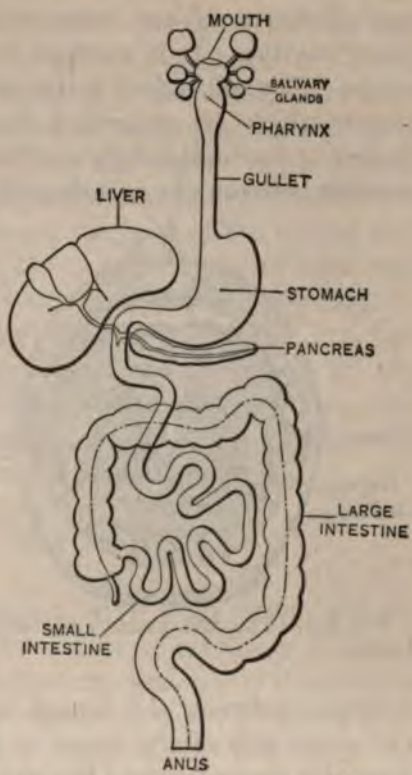


FIG. 111.—Diagram of the alimentary tube and its appendages. (Gerrish.)

Anatomy of the Digestive Apparatus

689. THE MOUTH OR BUCCAL CAVITY. — The mouth is an almost oval-shaped cavity which is bounded in front by the lips, on the sides by the cheeks, below by the larynx, above by the hard palate, and at the back by the pharynx.

690. THE HARD AND SOFT PALATES AND UVULA. —The hard palate is the bone which forms the

roof of the mouth and serves to divide it from the nasal cavities. It is covered with mucous membrane. The soft palate is the movable fold of soft tissue which is suspended from the posterior border of the hard palate and forms an incomplete septum between the mouth and the pharynx. Its central pointed portion is termed the uvula.[1] See Fig. 102 and 112.

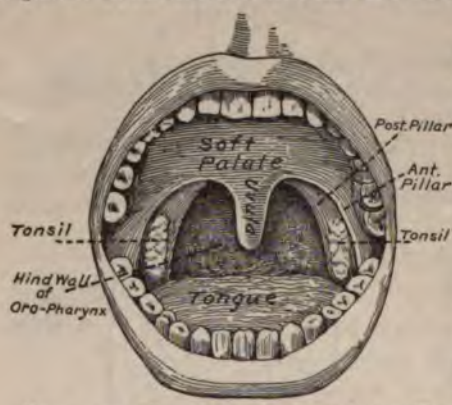


FIG. 112.—The soft palate and tonsillar regions.

691. THE FAUCES,[2] PALATINE ARCHES, AND TONSILS.—The *fauces* is the name given to the aperture between the mouth and the pharynx. On either side of the fauces is an arched fold of muscular tissue, covered like the rest of the mouth with mucous membrane. These are the *arches* or *pillars* of the *soft palate*, commonly known as the *palatine arches*. The top of each arch is at the base of the uvula. One of its pillars, called the *anterior pillar*, extends downward and forward to the base of the tongue, and the other pillar,

[1] From the Latin *uva*—a grape.
[2] From the Latin *faucis*—the throat.

named the *posterior pillar*, extends downward and backward to the sides of the pharynx. Lying between the anterior and posterior pillars of each of the palatine arches is an almond-shaped body called a *tonsil*. These are really lymph glands. During childhood there are many similar but smaller glands around the base of the tongue and extending up into the naso-pharynx. When large they are spoken of as adenoids. See page 257.

692. Accessory Organs Found in the Mouth.—The accessory organs found in the mouth are: the teeth, tongue, and openings to the ducts of the salivary glands. The teeth were described in Chapter V.

The Tongue

693. Why Classed with Digestive Organs.—The tongue is classed as an accessory organ of digestion for the following reasons: (1) it assists in swallowing; (2) the sense of taste, of which it is the principal seat, is one of the sources of the nerve impulses which start the secretion of the digestive juices; (3) the follicles at the back of the tongue secrete mucus which lubricates the food and aids in its passage to the stomach.

694. Nature and Connections.—The tongue is a freely movable muscular organ, or, rather, double organ, for its two sides, though united, are quite distinct, so that the function of one side need not necessarily be impaired because of dis-

ease or injury of the other. Its base or root is directed backward and connected to the hyoid bone by means of numerous muscles. It is connected with the epiglottis by folds of mucous membrane and with the soft palate of the anterior pillars of the palatine arches.

695. THE PAPILLÆ OF THE TONGUE.—The mucous membrane lining the under surface of the tongue is the same as that lining the rest of the buccal cavity, but that covering its upper surface differs in several respects, one point of difference being that it is studded by small projections called papillæ. These papillæ are of three varieties: (1) those called the circumvallate,[1] which are situated at the base of the tongue. These are larger than the other varieties and are circular in shape. They serve to secrete the mucus which lubricates the food and so helps in its deglutition; also they contain small structures known as *gustatory buds* or *taste goblets* containing filaments of the nerve of taste. (2) The papillæ next in size are the fungiform,[2] so called because their shape somewhat resembles that of mushrooms. They are situated principally on the tip and sides of the tongue. In each papilla there is a loop of capillaries and a nerve fiber derived from the glosso-pharyngeal —the special nerve of the sense of taste. The third and smallest set of papillæ are the *filiform*,

[1] From the Latin *circum*—around and *vallum*—a wall. So called because they are surrounded by a kind of wall.

[2] From the Latin *fungus*—a mushroom.

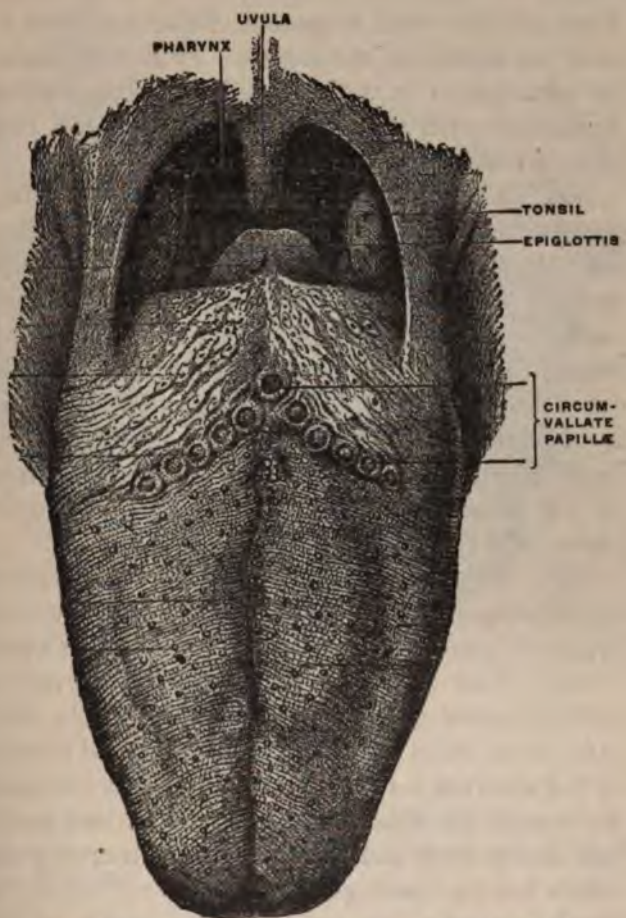


FIG. 113.—Dorsal surface of the tongue. (Gerrish.)

which, in man, are delicate, hair-like processes. They are the most numerous, being scattered all over the surface of the tongue. From their peculiar structure it is thought that these papillæ are concerned with the sense of touch, rather than that of taste.

696. NERVE SUPPLY.—The nerve-fibers which supply the papillæ and other parts of the tongue are: (1) filaments of the lingual nerve, which is derived from branches of the fifth or trifacial nerve, and the seventh or facial nerve. These are thought to give rise to the senses of touch and taste. (2) The ninth or glosso-pharyngeal nerve, which is concerned with the sense of taste. (3) The twelfth or hypoglossal nerve, which is distributed to the muscles of the tongue and is the motor nerve of the organ.

697. FUNCTIONS OF THE TONGUE.—In addition to assisting in deglutition, the tongue is the special organ of the sense of taste and assists in articulation.

698. THE SALIVARY GLANDS.—The principal salivary glands are: (1) the parotid[1] glands, situated one at each side of the face below and in front of the external ear. Each one communicates with the mouth by means of a duct about two and a half inches long and the diameter of a crow-quill, which has its openings on the inner surface of the cheek opposite the second molar tooth of the upper jaw. (2) The submaxillary[2] glands, situated

[1] From the Greek *para*—beside and *otos*—the ear.

[2] From the Latin prefix *sub* below and *maxilla*—a jaw.

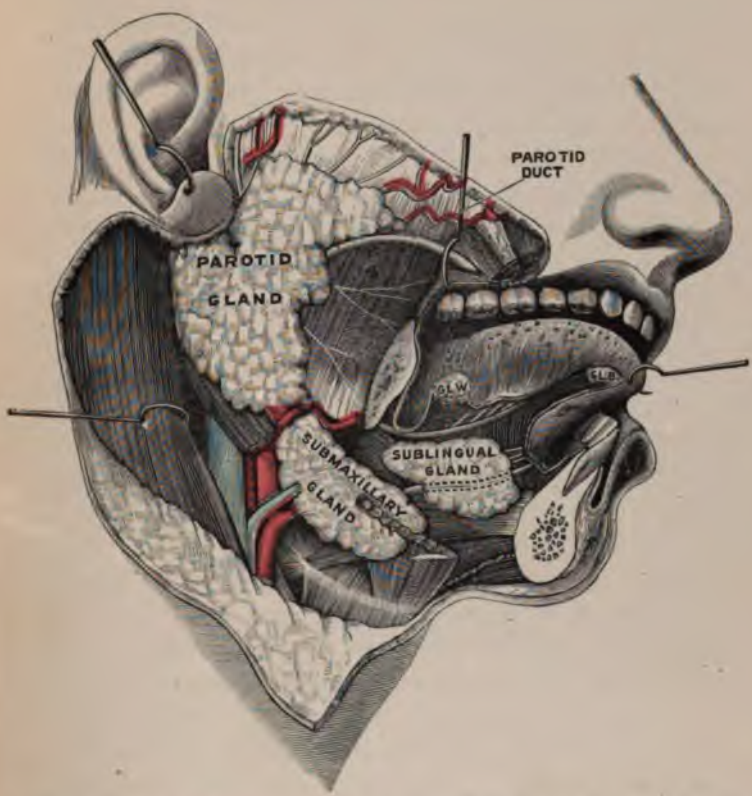


FIG. 114.—The salivary glands. The right half of the body of the mandible has been removed. GL. W., gland of Weber. GL. B., gland of Blandin. (Gerrish.)

below the jaw and opening into the floor of the mouth by means of ducts somewhat smaller than those of the parotid gland. (3) The sublingual[1] glands situated one on each side beneath the mucous membrane of the floor of the mouth, under the tongue, and opening into the mouth by numerous small ducts. (4) The mucous membrane of the mouth is studded with small glands which, like the larger glands, discharge their secretion into the mouth. The secretion from each set of glands differs slightly in composition; the whole combined is known as the saliva. Its function will be discussed in the next chapter.

PHARYNX.—The pharynx was described in connection with respiration in Chapter XV.

The Esophagus[2]

699. *Location.*—The esophagus is a muscular canal from about nine to ten inches in length, which has its origin at the lower end of the pharynx, behind the trachea. It descends in front of the spine, passes through the diaphragm and connects with the stomach just below the diaphragm, slightly to the left of the median line.

700. *Structure.*—The walls of the stomach are composed of three coats: (1) an external or muscular, (2) a middle or areolar, and (3) an internal or mucous coat. The fibers of the muscular coat are

[1] From the Latin *sub*—below and *lingua*—the tongue.
[2] From the Greek *oiso*—to carry and *phagein*—to eat.

arranged in two different planes; those of the outer plane run longitudinally and those of the inner plane run circularly. This arrangement is of importance in the peristaltic[1] movements which carry the food from the pharynx to the stomach. The areolar coat serves to connect the muscular and the mucous coats. The mucous coat is disposed in longitudinal folds that disappear on the distention of the tube. It is studded with minute papillæ and small glands which secrete a fluid to lubricate the canal.

The Abdomen

Before describing the organs of digestion situated in the abdomen it seems well to say something of the cavity in which they are contained.

701. LOCATION.—The abdominal cavity is situated between the diaphragm and the pelvic cavity. There is no partition between the two cavities, but the brim of the pelvis is considered the dividing line.

702. REGIONS OF THE ABDOMEN.—For convenience in the description of the location of the viscera, the abdomen is artificially divided into nine regions. The divisioning is as follows: two circular lines are supposed to be drawn around the abdomen, the one parallel with the cartilages of the ninth rib and the other with the highest joint of the crest of the ilia; this divides the abdomen

[1] From the Greek *peristello*—to compress.

into three zones—an upper, a middle, and a lower. Each of these three zones is supposedly subdivided into three parts by two parallel lines, one on each side of the abdomen, extending from the eighth rib to the center of Poupart's ligament. See Fig. 4.

The names of the nine regions and of the viscera contained in each region are as follows:

Right Hypochondriac	Epigastric.	Left Hypochondriac
The right lobe of the liver and the gall-bladder; hepatic flexure of the colon and part of the right kidney.	The middle and pyloric end of the stomach; left lobe of the liver; the pancreas; the duodenum; parts of the kidneys; and the suprarenal capsules.	The splenic end of the stomach; the spleen; extremity of the pancreas; the splenic flexure of the colon; and part of the right kidney.
Right Lumbar.	**Umbilical Region.**	**Left Lumbar**
Ascending colon; part of the right kidney and some convolutions of the small intestines.	The transverse colon; part of the great omentum and mesentery; transverse part of the duodenum, and part of the jejunum and ileum; part of both kidneys.	Descending colon; part of the omentum; part of the left kidney, and some convolutions of the small intestine.
Right Inguinal	**Hypogastric Region.**	**Left Inguinal.**
The cecum and vermiform appendix; the right ureter.	Convolutions of the small intestine; the bladder in children, and in adults if distended; and the uterus during pregnancy.	Sigmoid flexure of the colon; the left ureter.

703. The Peritoneum.[1]—The abdomen is lined with a serous membrane known as the peri-

[1] From the Greek *peri*—about and *teino*—I stretch.

toneum. This is a double membrane forming, in the male, a shut sac,[1] the outer or parietal layer of which lines the inner surface of the abdominal and pelvic cavities, and the inner or visceral layer is reflected back over the viscera.[2] In this respect the peritoneum resembles the pleura and pericardium, but the arrangement is much more complex than that of those membranes, for it has several elongated sacs or double folds extending from it which pass in between and either wholly or partially surround the various organs in the abdominal and pelvic cavities. One large fold, known as the mesentery,[3] invests the greater part of the small intestine, and its posterior portion extends backward and is gathered into folds which are attached to the spine; thus it serves to hold the intestines in place. Another important fold is the omentum.[4] This hangs like a curtain in front of the stomach and intestines, and as it contains considerable fat it serves, in addition to the usual functions of the peritoneum, to keep the organs it covers warm.

704. FUNCTIONS OF THE PERITONEUM.—This membrane serves to hold the abdominal and pelvic organs in position, to unite contiguous organs, and

[1] In the female, the peritoneum is not an absolutely closed sac, because the Fallopian tubes open into it at their extremities.

[2] The dorsal surface of the kidneys, the lower part of the rectum, bladder, and uterus, as well as small areas of some of the other organs, are not invested with peritoneum.

[3] From the Greek *mesos*—middle and *enteron*—intestine.

[4] Latin *omentum*—coverlet.

also to separate and prevent friction[1] between them; also it serves as a support for the numerous blood and lymphatic vessels and nerves passing to and from the viscera.

The Stomach

705. PURPOSE.—The stomach serves (1) to connect the esophagus with the small intestine; (2) to hold the food while it undergoes that part of the process of digestion known as chymification; (3) to secrete the fluids necessary for that process.

706. SHAPE, NAMES OF PARTS.—The stomach is the most distended portion of the alimentary canal. Its shape is that of a cone with its base placed upward and its apex downward, but bent sidewise to the right. There is an opening in the base which connects with the esophagus and one in the apex that opens into the small intestine. The former is called the *cardiac orifice* and the latter the *pylorus*[2] or *pyloric orifice*. The bending of the stomach causes its lower border to be much longer than its upper one; the lower border therefore is spoken of as the *greater curvature* and the upper as the *lesser curvature*. The rounded portion to the left of the esophagus is called the *body* or *fundus;*[3] the central portion is called the intermediate or prepyloric region; and the right extrem-

[1] The peritoneum, like all other serous membranes, prevents friction between adjacent parts by secreting a lubricating fluid.

[2] From the Greek *pulouros*—a gate-keeper.

[3] From the Latin *fundus*—the base of a cone-shaped organ.

ity, which is much constricted, is called the pyloric end.

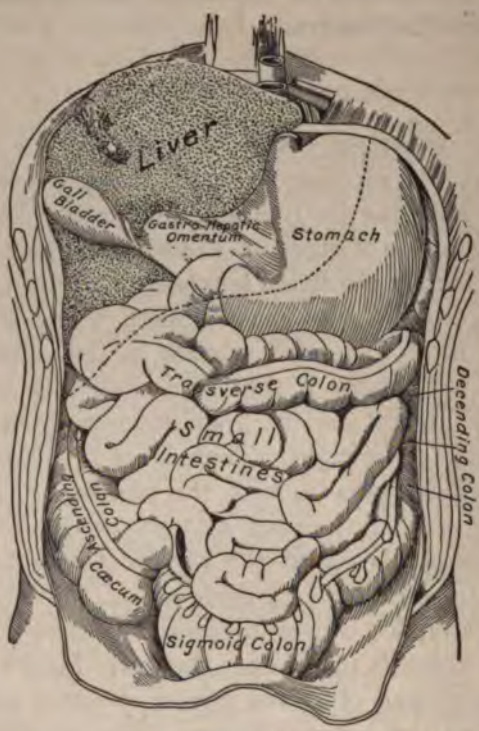


FIG. 115.—The stomach and intestine, front view, the great omentum having been removed and the liver turned up and to the right. The dotted line shows the normal position of the anterior border of the liver.

707. SIZE.—The size of the stomach depends upon the size of the individual and the quantity of

its contents. When moderately full the average transverse diameter of an adult's stomach is about twelve inches and its vertical four. When empty, the stomach is in a collapsed condition. The size of an infant's stomach at different ages is of importance for nurses to know. The average is as follows:

AGE.	CAPACITY OF STOMACH.
3d to 7th day	1 to 1½ ounces
7th day to 3d week	1½ to 2½ ounces
4th to 5th week	2½ to 3 ounces
6th week to 3d month	3 to 4½ ounces
3d month to 5th month	4 to 5½ ounces
5th month to 9th month	5½ to 8 ounces
9th month to 12th month	8 to 12 ounces

708. POSITION.—The stomach is situated in the left hypochondriac and epigastric regions of the abdomen, directly under the diaphragm. The fundus is behind the lower ribs and in contact with the spleen to which it is attached by folds of the omentum. The smaller or pyloric end extends slightly back of the liver.

709. COATS OF THE STOMACH WALLS.—The walls of the stomach are composed of four coats: (1) the outer or serous coat, which is a continuation of the peritoneum and entirely invests the organ except at the points of attachment of the omentum; (2) the muscular coat. This consists of three sets of fibers, the outer of which run longitudinally, the middle circularly, and the inner

obliquely—the oblique fibers are limited to the cardiac end of the stomach. This arrangement of the muscular fibers facilitates the peristaltic action of the stomach, because the longitudinal fibers contract as the circular ones dilate, and *vice versa*. (3) The areolar or submucous coat, which serves to connect the muscular and the (4) coat, which is the inner or mucous coat. This last has a thick, soft, velvety surface which when the organ is contracted is thrown into *folds* or *rugæ*. When examined under the microscope, this coat has a honeycomb appearance, due to the presence of numerous tubular glands or follicles which during digestion secrete the gastric juice, and certain of those in the prepyloric region secrete the hydrochloric acid. This will be further referred to in connection with digestion.

710. BLOOD AND NERVE SUPPLY.—The arteries supplying the stomach are the gastric and branches of the hepatic and splenic. The nerve supply is received from the sympathetic system and from branches of the pneumogastric or vagi.

The Small Intestine

711. PURPOSE.—The small intestine secretes the *succus entericus*, one of the juices that digests food, and it is in the small intestine that the greatest amount of digestion and absorption of food products takes place.

712. SIZE AND SITUATION.—The tube known

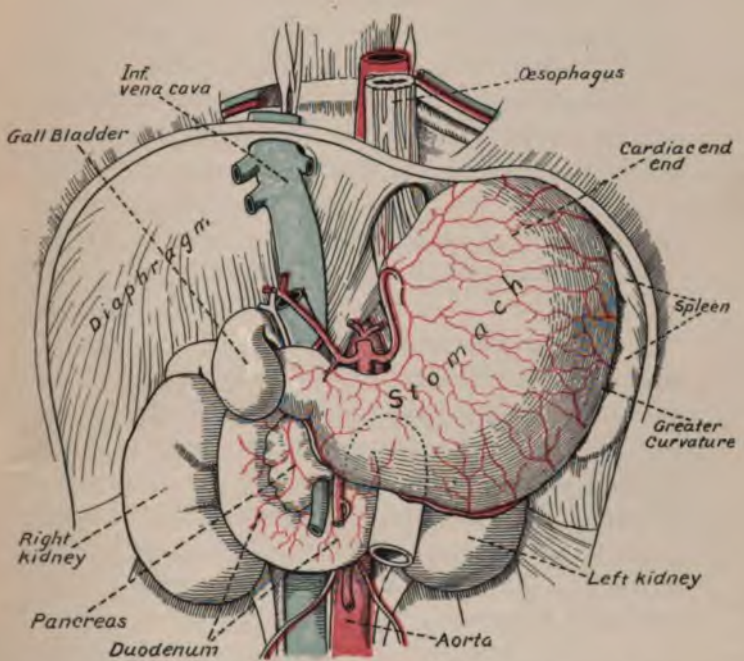


FIG. 116.—Stomach and duodenum. The liver and most of the intestines have been removed.

as the small intestine is about twenty feet in length and two inches in diameter at its commencement, *i. e.*, at the pyloric end of the stomach, but not more than one inch at its termination—the entrance to the large intestine. It is coiled up in the central and the lower part of the abdominal cavity and in the upper part of the pelvic cavity, and is held in position, as described in paragraph 703, by the mesentery.

713. Divisions of the Small Intestine.—For convenience of description, the small intestine is divided into three portions, known as the duodenum, the jejunum, and the ileum.

The **duodenum**[1] is the broadest and shortest portion of the small intestine, being, as the name implies, only twelve inches in length. It commences at the pylorus, curves obliquely slightly upward and backward to the under surface of the liver and then descends perpendicularly in front of the kidney and passes transversely across the lower portion of the spinal column, behind the colon, and terminates in the jejunum.

The **jejunum,**[2] so called because it is usually found empty after death, includes the upper two fifths of the rest of the small intestine.

The **ileum,**[3] so called from its numerous coils or convolutions, includes the remaining three fifths of the small intestine.

[1] From the Latin *duodeni*—twelve each.
[2] From the Latin *jejunus*—empty.
[3] From the Greek *eileō*—to twist.

714. STRUCTURE OF THE WALL OF THE SMALL INTESTINE.—The wall of the small intestine, like that of the stomach, consists of four coats: the serous, muscular, areolar, and mucous. The serous, which is the outer coat, is derived from the peritoneum. This invests the whole of the small intestine, except a small portion of the duodenum, and is continuous at the back with the mesentery folds which, it will be remembered, are attached to the spine. The muscular coat is arranged in two layers of fibers, one—the outer layer—arranged longitudinally, the other circularly. This arrangement is necessary for the peristaltic action of the intestine. The areolar or submucous coat serves to connect the muscular coat with the inner or mucous coat. The mucous coat is thick and highly vascular in the duodenum and jejunum, but becomes thinner and paler in the ileum. This and other conditions to be described later serve to make the upper portion of the intestine the most active part in digestion.

715. VALVULÆ CONNIVENTES.—From about two inches beyond the connection of the duodenum with the pylorus to the middle of the ileum, the mucous and submucous tissues are arranged in folds which extend around the cylinder of the intestine. Unlike the folds of the stomach, these do not disappear when the intestine is distended. They are called the valvulæ conniventes. Their purpose is twofold: (1) to prevent the food passing through the intestine too quickly; (2),to present a

greater surface for the absorption of the digested food.

716. VILLI.[1]—Through the whole length of the small intestine there are minute finger-like processes projecting from the mucous membrane; these are the villi. Each villus consists of a net-

FIG. 117.—Free surface of the mucous membrane of the small intestine, showing villi, solitary glands, and openings of the intestinal glands. Semidiagrammatic.

work of capillaries and a lacteal lymphatic vessel held together and supported by lymphoid tissue and covered by the mucous lining of the intestine. It is into the capillaries and lacteals of these villi that the food passes after it has been digested.

717. GLANDS.—There are also in the mucous membrane of the small intestine innumerable minute glands of four different varieties. These are known as:

[1] Villi, plural of *villus*, Latin—shaggy hair.

Simple follicles, or crypts of Lieberkühn[1]
Duodenal or Brunner's[1] glands
Solitary glands
Peyer's glands or patches

The **simple follicles** and **duodenal glands** serve to secrete the **succus entericus,**[2] *i. e.*, the intestinal digestive juice. The former are scattered all through the small intestine; the latter are contained only in the duodenum and commencement of the jejunum.

The **solitary glands** and **Peyer's patches** are lymph follicles. The former are scattered throughout the small intestine, but are more numerous in the lower part of the ileum. The latter are simply aggregations or patches of solitary glands. The patches are largest and most numerous in the ileum, hence the tenderness in the right iliac region in typhoid fever, in which disease these patches are inflamed and ulcerated.

The Large Intestine

718. PURPOSES.—(1) The continuation of the process of digestion. That digestion is carried on in the large intestine is due to the presence of bacteria and to the succus entericus with which the food became mixed in the small intestine. The fluid of the large intestine does not contain the enzymes necessary to activate the chemical

[1] So called from the men who described them.
[2] From the Latin *succus*—juice and *enteron*—the intestine.

processes of digestion. (2) Absorption. (3) The removal of waste products from the body.

719. SIZE AND POSITION.—The large intestine begins at the termination of the ileum in the right iliac region, and extends to the anus. It is, in the adult, about five feet in length.

720. DIVISIONS.—For convenience in description the large intestine is divided into the

- Cecum[1]
- Colon
  - Ascending
  - Transverse
  - Descending
  - Sigmoid flexure
- Rectum

The **cecum** is the dilated, pouch-like portion of the large intestine at its point of communication with the ileum. In order to prevent the passage of material back into the small intestine after it has once passed into the cecum, there is at the junction of these two parts a valve and sphincter known as the ileo cecal valve and sphincter.

The **vermiform appendix**[2] is a narrow, worm-like tube attached to the cecum. In man it is about three to six inches in length and about the diameter of a goose quill, but in lower mammalia it is much larger and is an important part of the intestine.

The **colon,** though one continuous tube, for

[1] From the Latin *caecus*—blind.

[2] From the Latin *vermis*—a worm and *forma*—shape.

convenience of description is divided into four parts, named: the ascending, transverse, descending colon, the sigmoid flexure, and the rectum. The ascending colon, which is continuous with the cecum, ascends to the under surface of the liver, where it bends abruptly to the left and becomes the transverse colon; this crosses the abdomen into the left hypochondriac region, curves beneath the lower end of the spleen, and then passes—as the descending colon—vertically downward to the upper part of the left iliac fossa; there it curves inward, forming the sigmoid flexure.[1] From this bend the intestine, under the name of rectum, extends obliquely downward and, after a slight curve forward, backward. The rectum measures from six to eight inches.

721. STRUCTURE.—The walls of the large intestine consist in some parts of four coats, but in others of three only, for the serous coat is lacking, or only partially covers some parts. The muscular coat, like that of the small intestine, consists of two layers of fibers, one arranged longitudinally and the other circularly. The third coat, as in the small intestine and stomach, consists of areolar tissue, and the fourth or inner coat consists of mucous membrane. The mucous coat of the large intestine contains numerous small follicles and solitary glands, but they are largely lymph glands

[1] This bend is called the sigmoid flexure because it curves like the letter S and *sigma* is the Greek word used to express the letter S, and from *eidos*—shape—S-shape.

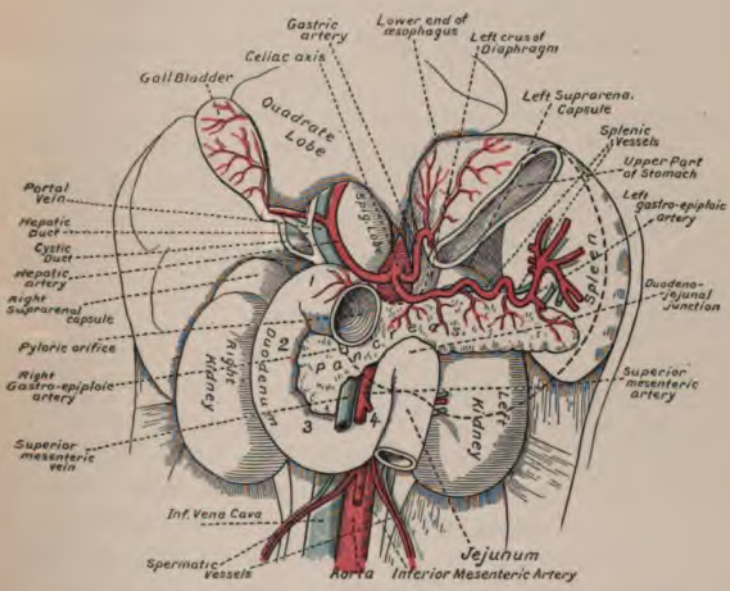


FIG. 118.—Relative position of the duodenum and pancreas. The liver has been lifted up and the greater part of the stomach removed; the dotted lines indicate the usual position of the latter.

and do not secrete digestive juice. There are no villi nor valvulæ conniventes in the large intestine, but there are a few circular folds above the rectum which prevent the too rapid urging of fecal matter toward the anus where its presence excites a desire for defecation. When the rectum is contracted the inner surface is thrown into longitudinal folds, but these disappear when the tube becomes distended.

722. THE ANUS.—This is the aperture leading from the large intestine to the exterior of the body. Except during defecation this orifice is kept closed by the contraction of the involuntary circular muscle known as the external sphincter.

The Pancreas[1]

723. PURPOSE.—Two secretions are formed in the pancreas: one, which is poured into the duodenum during intestinal digestion, constitutes about the most important of the digestive juices; the other, which is known as the internal secretion of the pancreas, is absorbed by the blood and carried to the tissues. Its use was discussed in paragraph 677.

724. SHAPE AND POSITION.—The shape of the pancreas is generally likened to a dog's tongue. The gland lies transversely in the abdomen, behind the stomach, and extends from the duodenum to the spleen.

[1] From the Greek *pan*—all and *kreas*—flesh.

725. SIZE.—The length of the pancreas varies from six to eight inches; its breadth is about one and a half inches, and it is from half an inch to one inch thick.

726. STRUCTURE.—The substance of the pancreas is composed of minute masses called lobules bound together with connective tissue into larger masses called lobes. Each lobule consists of a gland of the racemose type (see paragraphs 663 and 664). The small ducts from the glands of each lobe unite to form larger ducts, and these empty the secretion that has passed into them from the glands into the pancreatic duct. This duct extends through the center of the pancreas—from tip to base—and, uniting with the common bile duct (described in paragraph 738) opens into the duodenum.

727. ISLANDS OF LANGERHANS.—Scattered irregularly through the substance of the pancreas are collections of cells known as the *Islands of Langerhans*. It is thought that the internal secretion of the pancreas is formed in these cells.

728. BLOOD SUPPLY.—The numerous blood-vessels are derived from branches of the gastric, splenic, and hepatic arteries.

The Liver

729. FUNCTION.—The functions of the liver are more complex and numerous than those of any other gland in the body. It secretes the bile; it

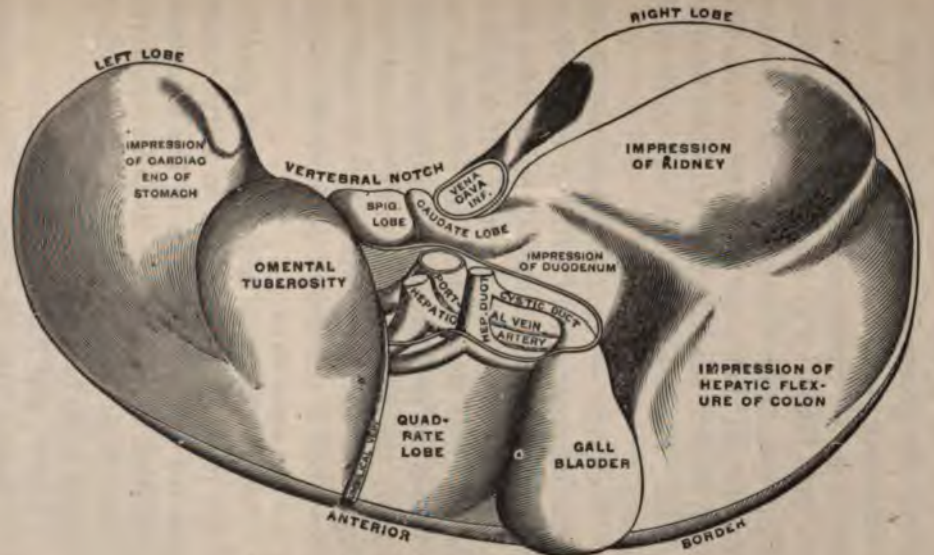


FIG. 119.—The liver, lower surface. (Gerrish.)

changes the glucose, brought to it from the intestine by the portal vein, into glycogen, and reconverts the glycogen into glucose when the latter substance is needed in the tissues; it acts as a storehouse for the glycogen; it forms the urea, which is then taken up by the blood and excreted by the kidneys; and it changes the nature of many toxic substances that arise from the putrefaction of protein food in the intestines into less harmful substances. These, like the urea, are excreted by the kidneys.

730. LOCATION.—The liver is situated directly below the diaphragm and in front of the right kidney, the upper part of the ascending colon and of the pyloric end of the stomach. It is held in position by five ligaments, four of which are derived from the peritoneum and connected to the diaphragm; the fifth is a round, fibrous cord resulting from the obliteration of the umbilical vein (described in paragraph 1036 which extends to the inferior vena cava.

731. SIZE.—The liver is the largest gland in the body; it weighs from fifty to sixty ounces, measures ten to twelve inches in the transverse diameter, from six to seven in its antero-posterior —*i. e.*, from front to back—and it is about three inches thick at its broadest part.

732. LOBES AND FISSURES.—The liver is divided by fissures into five lobes. These fissures serve also as channels to hold the large blood and lymphatic vessels and nerves, and the gall-bladder

fissure—in the under surface of the liver—supports the gall-bladder.

733. STRUCTURE.—The substance of the liver consists of an aggregation of lobules, blood and lymphatic vessels, and nerves, held together with delicate areolar tissue. The lobules measure from $\frac{1}{20}$ to $\frac{1}{10}$ of an inch in diameter. Each one consists of a mass of hepatic secretory cells that is surrounded and penetrated by capillaries, and of small ducts which arise from between the cells. Thus each lobule has all the essentials of a secretory gland; viz.: (1) cells by which the secretion is formed; (2) blood-vessels in close connection with the cells, containing the blood from which the secretion is derived; (3) ducts, by which the secretion is carried away. The outer surface of the liver is covered with an areolar coat called the *capsule of Glisson*, and this, except at the attachments of the ligaments and bottom of the fissures, is covered by a serous coat derived from the peritoneum.

734. BLOOD-VESSELS OF THE LIVER.—The hepatic artery and portal vein hold the blood flowing to the liver and the hepatic veins hold the blood which is leaving it. The hepatic artery and portal vein enter the liver at the same point—the *portal fissure*—and run together through the substance of the organ in small grooves called the *portal canals*. In their course through the liver they give off branches which divide and subdivide, and finally break up into capillary plexuses which

are distributed between the lobules. From these plexuses capillaries extend into the lobules converging toward the center and giving off branches which surround the liver cells. In the center of each lobule all the capillaries of the portal vein connect with a small vein—the intralobular[1] vein—that extends through the length of the lobule. At the base of the lobule the intralobular vein opens into what is known as a sublobular[2] vein. The sublobular veins unite to form the hepatic veins, and these in turn unite to form the three large hepatic trunks which empty into the inferior vena cava where it passes upward at the back of the liver. The branches from the hepatic artery follow those from the portal vein into the lobules and end in the capillary network surrounding the hepatic cells; thus the blood from the hepatic artery leaves the liver with that from the portal vein.

735. LYMPHATICS.—The lymphatic vessels of the liver are large and numerous. They assist in absorbing and carrying away some of the substances that collect as the result of activity of the liver and absorption from the blood.

736. NERVES.—The nerve supply of the liver is derived from branches of the pneumogastric or vagi and from the sympathetic system.

The Biliary Ducts of the Liver

737. PURPOSE.—The biliary ducts serve to collect the bile after it is secreted by the cells, and

[1] Within the lobule. [2] Under the lobule.

carry it during digestion to the duodenum, or, during the intervals when digestion is not going on, to the gall-bladder.

738. NAMES AND LOCATIONS OF THE DUCTS.—The names of the principal biliary ducts are: the *hepatic ducts*, the *cystic duct*, and the *common duct*.

The **hepatic ducts,** those which collect the bile as it is secreted by the liver cells, have their origin in the minute interspaces that exist between the hepatic cells. From these spaces numerous small capillary-like ducts arise in each lobule, and these uniting form an intralobular duct. The numerous intralobular ducts thus formed unite in turn to form larger ducts, and these converge to form two main ducts, one in the right and one in the left side of the liver. These two ducts join also, and by so doing form the chief *hepatic duct*. The large hepatic ducts pass from the liver in the same channel as the hepatic artery and portal vein, viz.: the *portal canal*.

The **cystic duct,** which is the passage-way for the bile to and from the gall-bladder, extends from the neck of the gall-bladder (see Fig. 119) to the hepatic duct and joins with it to form the common duct.

The **common duct** formed, as just stated, by the union of the hepatic and cystic ducts, serves to carry the bile from the other two ducts to the duodenum. It is about three inches in length and the diameter of a goose-quill. The orifice of the duct is situated about four inches below the

pylorus. It is very small and appears to be provided with a sphincter muscle, which keeps it closed when bile is not passing through. This, as has been previously said, is only during digestion.

739. SECRETION AND COLLECTION OF BILE.—The secretion of bile is continually going on, but is retarded in fasting and accelerated during digestion. It is formed in the hepatic cells—from substances brought to them by the blood-vessels—and discharged into the interspaces, whence it flows into the small ducts and thence to the hepatic duct. During intestinal digestion it passes through the common duct into the duodenum, but at other times it enters the cystic duct and some of it is stored in the gall-bladder until required. It does this because the sphincter at the orifice between the duct and duodenum is closed when the duodenum is empty. When food enters the intestine the stimulus of the food excites contractions which relax the sphincter and allows the passage of bile from the gall-bladder and liver.

The Gall-Bladder

740. SHAPE AND SIZE.—The gall-bladder, which is the reservoir for the bile, is a pear-shaped organ, about four inches in length and one inch in breadth at its widest part. It holds about eight to ten drams.

741. LOCATION.—It is situated in the *gall-bladder fissure*, on the under surface of the liver,

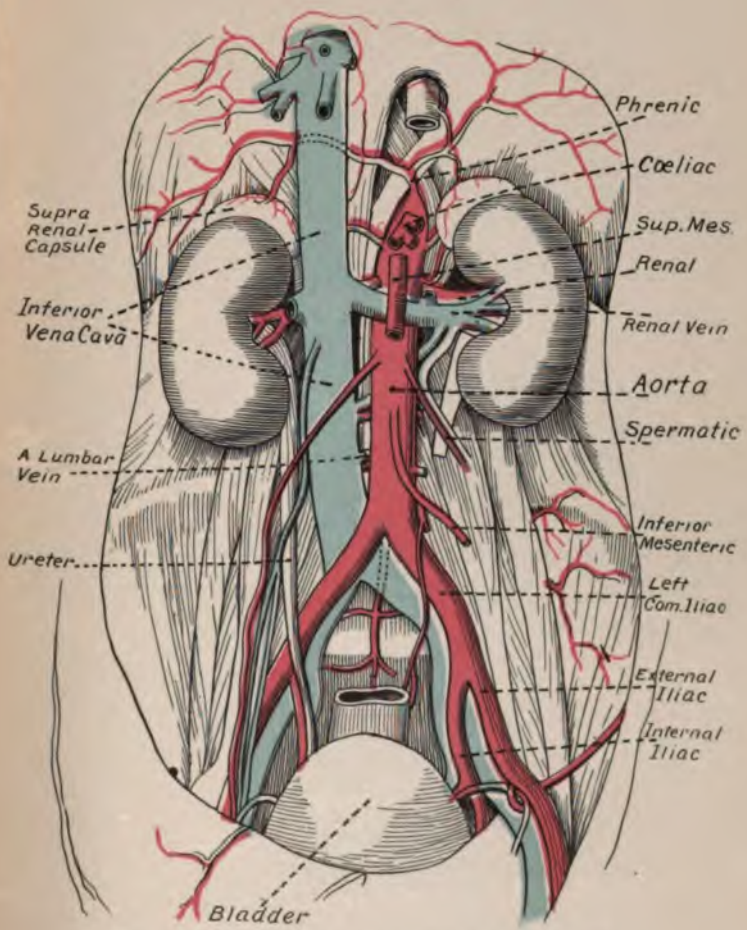


FIG. 120.—Abdominal aorta and inferior vena cava.

and is held in position by folds of peritoneum which are attached to the liver.

742. STRUCTURE.—The walls of the gall-bladder are composed of three coats: the outer one is of serous membrane; the middle of muscular and fibrous tissue; and the internal of mucous membrane.

CHAPTER XVIII

FOOD. DIGESTION. ABSORPTION

Classification of Food. Chemical Composition of Food. Uses of Organic and Inorganic Food Substances. Reasons for Digestion. Nature and Action of Enzymes. Nature of Digestive Juices. Mechanism of the Secretion of Digestive Fluids. Organs in which the Digestion of the Various Foodstuffs Takes Place. Influence of Bacteria on Digestion. Mechanical Processes of Digestion. Defecation. Nature of Feces. Where Absorption Takes Place. Nature of Absorption.

743. DEFINITION OF DIGESTION.—By digestion is meant the process which takes place in the alimentary canal whereby food is made soluble and of such a nature that it can pass through the walls of the intestinal blood-vessels, be absorbed by the blood, and be utilized by the body for the building and repair of tissue and the production of heat and energy.

In order to understand the changes which take place in food during digestion and the purposes for which it is used after it has been digested and absorbed, it is necessary to know something of the chemical nature of the substances used as food. Therefore, the next few pages will be devoted to their description.

744. CLASSIFICATION OF FOOD.—Foods may be divided into two classes:

1. Organic
2. Inorganic

Organic foods are subdivided into:

Proteins
Carbohydrates
Fats

Inorganic foods are subdivided into:

Mineral matter
Water

745. PROTEINS.—Examples of the protein substances are: (1) *Albumin*, *e. g.*, the white substance seen when egg is heated; the scum that forms on the top of milk when its temperature is raised above 170° F.; the white coating that forms on meat when it has been in a hot oven for a short time. (2) *Caseinogen*,[1] *e. g.*, the substance that is formed into a curd when acid or rennet is added to milk, or when milk sours.[2] (3) *Gluten*, *e. g.*, the gummy substance in wheat. (4) *Legumin*, a protein substance contained in the class of vegetables known as the legumes, *e. g.*, beans, peas, lentils. (5) Gelatin. (6) Extractives, *e. g.*, simple protein substances which are formed in both animal and

[1] From the Latin *caseus*—cheese.

[2] Milk becomes sour because the sugar it contains—lactose—is, under the influence of bacteria, changed to lactic acid.

plant bodies as the result of metabolism. Meats and many plants owe their flavor to extractives.

746. CHEMICAL ELEMENTS OF ORGANIC FOOD.—The elements of which proteins are formed are: carbon, hydrogen, oxygen, nitrogen, sulphur, and, usually, phosphorus and iron. The proteins are often called the nitrogenous foodstuffs, because they contain nitrogen and the carbohydrates and fats do not. The carbohydrates and fats contain only carbon, hydrogen, and oxygen; the fats having much less oxygen than the carbohydrates.

747. VARIETIES OF CARBOHYDRATES.—The foodstuffs classed as carbohydrates are the amyloses[1] or polysaccharids[2] and the sugars.

748. THE AMYLOSES.—The group of substances known as amyloses are: starch, dextrine,[3] cellulose,[4] glycogen,[5] and gums. These are of a much more complex structure than the sugars. Each molecule of an amylose consists of a number of molecules, each one of which is made up of 6 atoms of carbon, 10 atoms of hydrogen, 5 atoms of oxygen ($C_6 H_{10} O_5$).

749. CLASSIFICATION AND NATURE OF SUGARS.

[1] From the Latin *amylum*—starch.

[2] From the Greek *polus*—many, and Latin *saccharum*—sugar.

[3] Dextrine is formed from starch in the process of digestion and by the action of heat; the browned part of toasted bread is an example.

[4] Examples: the rind and fibrous parts of vegetables and other plants.

[5] Called also animal starch. This will be described in paragraph 799.

—Sugars, according to their chemical composition, are divided into two classes: (1) the disaccharids[1] or sucroses; (2) the monosaccharids or glucoses.

The **sucroses** are: cane sugar, beet sugar, maple sugar, maltose (sugar of malt), and lactose (sugar of milk). Each molecule of these sugars consists of 12 atoms of carbon, 22 atoms of hydrogen, 11 atoms of oxygen ($C_{12} H_{22} O_{11}$).

The **glucoses** are: glucose or dextrose[2]; fruit sugar or levulose[3]; invert sugar. Glucose and levulose are both found in fruit. Invert sugar, of which honey is a familiar example, consists of a mixture of the two. Glucose can be made by boiling polysaccharids or disaccharids in dilute acids, and in the animal body it is formed as the result of the digestion of polysaccharids and disaccharids. The monosaccharids consist of 6 atoms of carbon, 12 atoms of hydrogen, and 6 atoms of oxygen. Thus, it will be seen, one molecule of a disaccharid ($C_{12} H_{22} O_{11}$) plus one molecule of H_2O will yield two molecules of a monosaccharid, $C_6 H_{12} O_6$.

750. FATS.—Fats and oils are practically the same, oils being fats that are liquid at ordinary temperature. Like the carbohydrates, they consist of carbon, hydrogen, and oxygen; but the last-named element is present only in small quantities.

[1] From the Greek *dis*—twice, and Latin *saccharum*—sugar.

[2] From the Latin *dexter*—the right.

[3] From the Latin *lævus*—the left.

The sugars were so named because dextrose deflects polarized light to the right and levulose causes it to deviate to the left.

The ordinary fats and oils of animal and vegetable foods are not simple fats, but consist of a mixture of simple fats, the principal ones of which are known as stearin, olein, and palmitin. These simple fats also are compound substances, and each molecule of a simple fat is made up of three molecules of a fatty acid and one molecule of glycerine. The fatty acids of which the above simple fats are composed are called stearic, oleic, and palmitic acids.

751. SOLUBILITY AND DECOMPOSITION OF FATS. —Fats are insoluble in water and in cold alcohols, but are soluble in hot alcohol, ether, chloroform, and similar substances. They are easily decomposed or saponified by alkalies or super-heated steam into their constituent parts—fatty acids and glycerine.

752. LECITHIN.—This is a substance that is usually classed with the fats, because the manner of its digestion is similar to that of the latter, and it somewhat resembles them in its composition; but it contains only two molecules of fatty acid, the third one being replaced by a protein molecule. This protein molecule contains phosphorus and, of course, nitrogen; therefore, lecithin is often spoken of as a *phosphorized fat*, or as a *nitrogenous fat*. It is found in small quantities in many substances, but is contained chiefly in the yolk of egg and nerve tissue. It is an important constituent of the latter.

753. CHOLESTERINE.—This is a fat-like sub-

stance, but it is not a true fat. Its chemical composition is similar to an alcohol. It is contained in many of the body tissues and also in plants.

754. Uses of Organic Food-Substances.—These are: (1) To build the body tissues and to repair the constant waste that is going on in the body as the result of muscular activity. (2) To supply heat to keep the body warm. (3) To provide the energy necessary to maintain the functional activities of the body. The different parts of the body machinery—the heart, lungs, nervous system, etc.—can no more keep active unless they are supplied with power or energy than can machinery constructed by man.

Inorganic Foods

755. As previously stated, the inorganic food principles are: inorganic salts and water.

The principal inorganic salts contained in food are:

Carbonate, Chloride, Phosphate and Sulphate	of Sodium and Potassium	Carbonate and Phosphate	of Calcium and Magnesium

756. Uses of Inorganic Salts.—The inorganic salts taken into the body in food are not oxidized and, therefore, have no fuel value; nevertheless they are absolutely indispensable to the life of the body. Some of their more important

uses are as follows: They form an essential part of the tissues of the body. They maintain the normal osmotic pressure in the liquids and tissues of the body, and in this way help in regulating the flow of fluids to and from the tissues. The calcium salts are of importance in maintaining the irritability of nerve and muscle and the firm consistency of bone; also, they are necessary for the clotting of the blood. The chlorides of sodium, potassium, and calcium are necessary to maintain the rhythmical contraction and relaxing of the heart muscle. Sodium chloride is necessary for the manufacture of the hydrochloric acid of the gastric juice, and iron for the production of hemoglobin and for oxidative processes.

Water

757. FUNCTION.—Water, like mineral matter, does not give rise to heat and energy, but is nevertheless essential to life. It enters into the composition of even the hardest tissues, such as cartilage and bone; it supplies fluid for the body; it acts as a solvent for food; and is necessary for the removal of waste matter.

Digestion

758. WHY NECESSARY.—Water and salts are absorbed into the system unchanged, the salts being soluble in water, but all organic foods except the sugars must undergo certain chemical changes before they are capable of passing through

the walls of the stomach and intestines, and thence into the blood-vessels and lacteals. One reason for this is that with the exception of the sugars the organic foods are not soluble—*i. e.*, they cannot be dissolved—in water. The sugars are soluble in water, but the disaccharids—*i. e.*, cane sugar, etc.—cannot be utilized in the system unless they are changed to glucose in the alimentary canal. If they are introduced into the blood in their natural state they will be excreted at once through the kidneys. The body cannot use them, and therefore it gets rid of them as quickly as possible, just as it does poisons.

759. Types of Digestive Processes.—Digestion comprises two distinct kinds of processes; one mechanical and the other chemical.

760. Mechanical Processes.—The mechanical processes consist of:

1. Mastication
2. Deglutition or swallowing
3. Peristaltic action of the esophagus, stomach, and intestines
4. Defecation

761. Nature of Chemical Digestion.—Chemical digestion consists of what is known as hydrolysis,[1] *i. e.*, the absorption of water and splitting of the complex molecules of the food substances into more simple ones. For example, each molecule of cane sugar consists of C_{12} H_{22}

[1] See Glossary.

O_{11}. When this has undergone hydrolysis and thereby been changed to glucose, it consists of 2 molecules of $C_6 H_{12} O_6$. Thus each molecule of glucose represents half the molecule of cane-sugar plus a molecule of water, H_2O. In the disaccharids only one splitting is necessary, therefore they are quickly and easily digested, but the molecules of starch[1] must undergo several divisionings before they are changed to glucose. Each splitting of the molecules causes certain changes in the nature of the starch, and the substance produced by each divisioning is known by different names. Thus, as the result of the first splitting we have dextrin, of which there are three varieties, each one being produced as a result of a further splitting of the molecules; then maltose is yielded, and, finally, glucose. Protein substances being of a still more complex nature must undergo an even greater number of divisionings than starches.

The names of the principal classes of substances so formed are: acid-proteins, proteoses, peptones, polypeptids, and amino-acids. Peptones are soluble and can be absorbed, and some physiologists think that a considerable proportion of the proteins may not go beyond this stage in digestion. Fats, as a result of chemical digestion, are first split into fatty acids and glycerine; the fatty acids then unite with alkaline substances of the bile and pancreatic juice and form soap.

[1] It will be remembered that starch consists of a number of molecules of $C_{12} H_{10} O_5$.

762. CAUSE OF CHEMICAL CHANGES.—Outside the body, the carbohydrates and proteins can be made to undergo the same changes as those which occur in digestion by boiling them with acid, or by the addition of specific ferments,[1] and fats will be saponified if boiled with alkalies. Within the body the changes take place at a comparatively low temperature, 99° to 100° F., and that they do so is now universally attributed to the presence of organic catalyzers[2] called ferments or enzymes in the digestive juices of the stomach, small intestine, and pancreas.

763. NATURE OF ENZYMES.—The exact composition of enzymes is not known. Professor Howell defines them as "organic substances derived from proteins and of a colloidal nature."[3] They are called catalyzers because, like the inorganic catalyzers, they hasten reactions but do not initiate them, and are not used up in the reaction. Enzymes are specific in their action, *i. e.*, the enzyme that aids in the digestion of one food-stuff will have no effect upon the others. Enzymes are affected by temperature, the body temperature is the optimum; a high degree of heat will destroy them, a low temperature will retard their action. Their activity is altered also by the reaction of

[1] The ferments used to digest starches are made from the glutin of wheat; those used for protein from the pancreas or stomach of animals.

[2] See Glossary.

[3] *Text-Book of Physiology*, page 717. William H. Howell. W. B. Saunders Co.

their surroundings. The enzyme of the saliva requires a neutral or slightly alkaline medium; those of the gastric juice require an acid; those of the pancreatic and intestinal juices require an alkaline.

764. NATURE OF THE DIGESTIVE JUICES.—The digestive juices consist principally of water, mucin[1] salts, specific enzymes, and, in the case of the gastric juice, hydrochloric acid.

765. FUNCTION OF THE HYDROCHLORIC ACID.—Hydrochloric acid, which during digestion is secreted by special gastric cells at the expense of the chlorides of the blood in sufficient quantity to be present in the gastric juice in the proportion of 0.2 to 0.4 per cent., is a most important adjunct in gastric digestion. It activates the pepsin; helps in the inversion of sugar; acts as a disinfectant, killing many bacteria that gain entrance to the stomach; and regulates the passing of food from the stomach into the intestine. How this last action is produced will be described in paragraph 787.

766. MECHANISM OF THE SECRETION OF THE DIGESTIVE FLUIDS.—*Saliva.*—The flow of saliva from the salivary glands is the result of reflex stimulation of the secretory nerves connected with those glands. For instance, certain sensory nerves are stimulated by the movements of the mouth, the taste and odor of food, etc. The impulses thus started are carried to a nerve-center—thought to

[1] An albuminoid constituent of mucus.

be in the medulla oblongata—and from thence motor impulses are transmitted through the efferent nerves to the gland, and the gland is stimulated to activity. The secretion of saliva may be influenced also by psychical acts, *e. g.*, it may be excited by the thought of savory food, feeling of nausea, etc., and inhibited by such sensations as anger, fear, and worry.

767. GASTRIC JUICE.—When the stomach is inactive, *i.e.*, when there is no food in it, no gastric fluid is secreted, and its inner surface is covered with mucus of a neutral or alkaline reaction, but immediately upon the entrance of food into the stomach the gastric glands commence secreting and an acid fluid is poured out over the walls of the organ. The factors causing this secretion are: (1) the sensations of eating, and the taste and odor of the food; the sensory nerves producing this stimulation are situated in the mouth and nose, and the motor impulses are carried to the stomach by the vagus nerve; (2) the action of substances known as *secretogogues* contained in certain foods; meat juices and extracts are particularly rich in these substances, but milk, bread, white of egg, and similar substances do not appear to have any. How these secretogogues act is not known, but it has been suggested[1] that "they act upon the pyloric mucous membrane and form a substance which Edkins designates as gastrin or gastric

[1] *Text-Book of Physiology*, pages 748–749. William H. Howell. W. B. Saunders Co.

secretin, and this substance, after absorption into the blood, is carried to the gastric glands and stimulates them to secretion."

The secretion of gastric juice, like that of the saliva, is greatly affected by psychical influences, thus pleasant flavors, odors, etc., will induce secretion, and distaste of the food, anger, worry, etc., will inhibit secretion. Secretion is retarded also if the blood supply to the stomach is interfered with, as by active exercise soon after a meal.

768. PANCREATIC SECRETION.—The principal agent influencing pancreatic secretion is the gastric juice. When the acid chyme enters the intestine it acts upon a substance called *prosecretin* present in the mucous membrane of the intestine, thereby producing *secretin* which is carried by the blood to the pancreas and stimulates the action of that gland.

769. SUCCUS ENTERICUS—*Intestinal Secretion.*—The succus entericus or intestinal juice flows from the glands of Lieberkühn in the small intestine. The mechanism of its secretion is very imperfectly known.

770. THE BILE.—This consists of waste substances derived from the blood and arising in the liver. It contains water, mucin, pigment, bile, and inorganic salts, fat, lecithin, and cholesterin.

771. The names of the enzymes contained in the various digestive juices and their action on the food can be seen in the following table:

Digestive Juices.	Enzymes.	Action on Food.
Saliva	Ptyalin	Turns starch to dextrin and maltose
	Maltase	Turns maltose to dextrose
Gastric juice	Rennin	Coagulates milk
	Pepsin + Hydrochloric[1] acid	Splits proteins to proteoses and peptones
		Slight inversion of sugar by HCl
	Gastric lipase	Commences the digestion of emulsified fats, as cream
Pancreatic juice	Amylopsin	Continues work of ptyalin
	Trypsinogen[2]	Continues work of pepsin, splitting proteoses into peptones and amino-acids
	Lipase or steapsin	Decomposes fats into fatty acids and glycerin
Intestinal juice	Erepsin	Continues work of pepsin and trypsin, splitting peptones to amino-acids
	Sucrase	Inverts sucroses to dextrose—glucose—and levulose
	Maltase	Changes maltose to dextrose
	Lactase	Changes lactose to dextrose
Bile	No known enzyme	Aids lipase in splitting fats to fatty acids and glycerin. Assists the alkalies of the intestinal and pancreatic juices in the saponification of the fatty acids and aids in their absorption

Organs in which Digestion of the Various Food-Stuffs Takes Place

772. Changes Occurring in the Mouth.—As can be seen by the foregoing table, though all food is acted upon mechanically while in the mouth—*i. e.*, broken by the teeth, moistened with saliva, and made into a bolus that can be easily swallowed—it is only starch in which any chemical change takes place.

[1] Hydrochloric acid is not an enzyme.

[2] Trypsinogen is a zymogen or antecedent of an enzyme. It is inactive until it comes in contact with an activating enzyme—or hormones—called enterokimase, secreted by the intestinal cells, which activates it, changing it into trypsin.

773. STARCH.—The starch is changed partially to dextrine and maltose by the ptyalin and to dextrose by the maltase of the saliva, but digestion is not completed because the food remains in the mouth such a short time, and though the action of these enzymes is continued for a short time after the food enters the stomach, they are destroyed as soon as the food becomes acidulated. The amylopsin of the pancreatic juice is therefore necessary to complete the change to maltose and the maltose of the intestinal juice to invert the maltose to dextrose. The pancreatic and intestinal juices become mixed with the food while it is in the duodenum.

774. PROTEIN.—The chemical digestion of the protein foods begins in the stomach, by the action of the pepsin plus the hydrochloric acid; it is continued in the duodenum by the trypsin of the pancreatic juice and the erepsin of the intestinal juice.

775. FATS.—Emulsified fats, such as cream, are split into fatty acids and glycerin by the gastric lipase, but other fats undergo no change in the stomach. In the duodenum, the steapsin or, as it is now often called, lipase[1] splits them to fatty acids and glycerin, and the alkalies of the bile, pancreatic, and intestinal juices saponify them.

776. SUGARS.—Sugars, like fats, undergo little change until they reach the duodenum. The acid

[1] The chemical name for fats is lepins, from the Greek *lipose*—fat.

of the gastric juice may cause some slight change, but it is the ferments—sucrase, lactase, and maltase—that invert the sucrose, lactose, and maltose, respectively, to glucose.

777. Chyme and Chyle.—The thick liquid substance resulting at the end of gastric digestion is called *chyme*. The milky-colored emulsion occurring as the result of the digestion of fats in the duodenum is termed *chyle*.

778. Influence of Bacteria on Digestion.—Bacteria are always present in the intestine and take an active, though not indispensable, part in the breaking-up of food substances. Normally, only bacteria capable of producing fermentation of carbohydrates are active in the small intestine, but, in the large intestine, those producing putrefaction of proteins are the most common. Bacteria which cause fermentation and those that produce putrefaction do not seem to thrive together; some authorities think that this is because the bacteria are antagonistic to each other; others think that the acids produced in the process of fermentation destroy, or render inert, the putrefaction-producing bacteria. If excessive fermentation takes place, gases will be formed and flatulence result. If much putrefaction occurs, protein digestion is carried beyond the amino-acid stage and substances such as indol, skatol, and various gases as carbon-dioxide, sulphurated hydrogen, etc., result. When not in excess these substances pass off in the feces, and it is to such

matter as indol and skatol that the odor of the feces is due. When these substances are formed in abnormal amounts, or when their elimination is retarded, they are absorbed, carried to the liver where they undergo certain changes, and are then carried to the kidneys and excreted in the urine. The indol is changed to indican in the liver. The amount of this substance present in the urine is therefore an indication of the extent of putrefaction going on in the large intestine. The products of putrefaction are more or less poisonous, and when formed in sufficient quantities to be absorbed they are likely to give rise to such symptoms as headache, general lassitude, etc. Also, it is thought that when they are frequently present in the system they induce premature sclerosis or hardening of the arteries and, consequently, the conditions of *old age*.

779. MECHANICAL PROCESS OF DIGESTION.—As stated in paragraph 760, the mechanical process of digestion consists of:

Mastication
Deglutition
Peristaltic[1] action of the stomach
Peristaltic[1] action of the intestine
Defecation

[1] From the Greek *peristello*—to compress.

The waves of contraction that pass slowly over the stomach and along the intestine resemble in appearance the movements of a worm. The nature of the movement is due to the arrangement of the muscular fibers in the walls of the esophagus, stomach,

780. Nature of Mastication.—Mastication is a voluntary act which takes place in the mouth. The teeth grind the food into small pieces, while the movements of the tongue and of the muscles of the cheeks and lips help to hold it in place between the teeth and to gather it into such a position that it can be swallowed. During the process of mastication the food becomes mixed with saliva.

781. Necessity for Mastication.—Unless food is properly masticated it enters the stomach in pieces that are too large, and gives that organ more mechanical work than it is fitted for. Also, the food does not become properly mixed with saliva, and in the case of starches it is very important that it should be so mixed.

782. Deglutition.—The act of swallowing is at first a voluntary action, but after the bolus of food passes the orifice of the esophagus the act is involuntary, and is assisted by the peristaltic action of the esophagus. This action is the result of reflex nervous stimulation caused by the presence of the food. Liquid or very soft food is shot through the canal by the initial act of swallowing and reaches the cardiac opening of the stomach 0.1 second after it has been swallowed, but solid food takes almost 4.6 to 8.6 seconds to pass through the esophagus. The orifice to the stomach

and intestines, which, it will be remembered, are in two layers, those in one layer being arranged longitudinally and those of the other transversely, so that they encircle the organs.

is guarded by a valve which does not open until the worm-like wave which passes slowly down the esophagus reaches the stomach, and the fluid food which passed through the canal quicker than the wave will have to wait until the wave started by its deglutition reaches the stomach, unless the valve has been previously opened for the passage of food.

783. VOMITING.—The valve between the esophagus and stomach prevents the regurgitation of food under ordinary circumstances, but if for any reason strong contractions are started in the stomach, it may open and the food return through the esophagus. This is called vomiting.

784. PERISTALTIC ACTION OF THE STOMACH.—In order to understand how the mechanical action of the stomach can perform its function it is necessary to remember that the cavity of the stomach is always the size of its contents. When it is empty, the stomach is uniformly constricted; as food enters, the stomach expands sufficiently to hold it; as the food passes into the intestine the stomach contracts so that its walls continue to press upon its contents. This condition enables the worm-like wave of contraction (which passes at regular intervals over the intermediary and pyloric portions of the stomach from the moment food enters it) to press upon the food, macerating it, mixing it with gastric juice, and from time to time ejecting a small portion of it into the intestine.

785. FUNCTION OF THE FUNDUS.—There seems

to be little or no movement in that part of the stomach known as the fundus, but so long as it contains food its muscles are in a state of tone. Both these facts are of importance to gastric digestion: (1) On account of the lack of movement, a large part of the food entering the stomach remains undisturbed for some time and does not become saturated with the gastric juice, and so long as this is the case the ptyalin that became mixed with the food while it was in the mouth can continue its action on the starch, but the ptyalin is rendered inactive as soon as the food becomes moistened with the acid gastric juice. (2) The special value of the tonicity of the fundus muscle is the pressure that it exerts on the food lying beneath it, because this pushes the food forward as the contents of the pyloric end of the stomach are gradually ejected into the duodenum.

786. Time Required for Gastric Digestion.—It requires about five hours to complete the gastric digestion of an average meal of mixed food, *i. e.*, meat, vegetables, etc.

787. Factors Regulating the Passage of Food into the Duodenum.—Since the invention of the X-ray apparatus, the theories regarding the discharge of the chyme into the intestine have been very much changed. Formerly it was thought that the greater part of the food taken at a time remained in the stomach until gastric digestion was completed, but by means of the X-rays it has been found that small quantities of chyme are

ejected from the stomach through the pyloric orifice at more or less regular intervals. The factors which are thought to regulate the relaxing and contraction of the sphincter muscle controlling the pyloric orifice and, consequently, the passage of the chyme are: (1) the consistency and (2) the acidity of the chyme. Solid particles against the pylorus tend to keep the sphincter closed. The way in which the acid is produced and acts is as follows: When the stomach is empty the inner surface of that organ is covered with mucus that is either neutral or slightly alkaline in reaction, but immediately upon the entrance of food the secretory cells contained in the mucous lining of the stomach begin to secrete the gastric juice, and certain of them the hydrochloric acid. The latter unites with the protein substances, for which it has a strong affinity, but after the proteins become saturated there is free hydrochloric acid in the gastric fluid, and when this occurs the pyloric sphincter relaxes and some of the chyme passes into the intestine. As soon, however, as a sufficient amount of the acid chyme has entered the intestine to render the alkaline contents of the pyloric end of the duodenum acid, the orifice closes, and remains closed until an alkaline reaction is once more regained.[1]

788. MOVEMENTS OF THE SMALL INTESTINE.—

[1] A description of the experiments by which these facts were ascertained will be found in *Text-Book of Physiology*, Chapter XXXIX. William H. Howell. W. B. Saunders Co.

The movements of the small intestine are of two kinds: (1) a peristaltic action, which passes the substance received from the stomach slowly onward; (2) a series of local constrictions, which forces it into the folds and against the surface of the valvulæ conniventes, thus assisting in mixing it with the digestive juices as well as aiding in its absorption. Also, the movements of the intestine, by causing an intermittent pressure on the blood-vessels and lacteals in the walls of the bowel, assist in the carrying away of the digested food substances after they have been absorbed.

789. Passage of Food Material through the Large Intestine.—The food substance not absorbed in the small intestine passes through the ileo-cecal valve into the cecum and, under normal conditions,[1] its regurgitation is prevented by the closure of the valve. When the cecum becomes filled, strong constriction waves press the walls of the cecum upon the food and force it onward into the ascending colon and, also, induce absorption. The peristaltic waves which pass over the walls of the ascending and transverse colon are different from those in other parts of the organ in that they pass both from and toward the small intestine. This keeps the food moving backward and forward and thus prevents its too rapid expulsion from the bowel, and facilitates

[1] Obstruction in the large intestine will cause fecal matter to regurgitate into the small intestine, and thence it may pass into the stomach and be vomited.

absorption—food requires six or seven hours to pass through the colon. The introduction of liquid into the intestine via the rectum induces an *antiperistaltic* action that carries the fluid upward.

790. DEFECATION.—The sphincter muscles, whereby the relaxing and contraction of the anus are controlled, are involuntary muscles, but they are supplied with nerves from the cerebro-spinal system; therefore their action and, consequently, defecation can be controlled by the will. The voluntary action in defecation consists mainly in the contraction of the abdominal muscles, which, by causing pressure upon the intestines, forces their contents into the rectum. The desire for defecation arises from irritation of sensory nerve endings by an accumulation of feces in the lower part of the intestine. The sense of irritation often becomes diminished by failure to evacuate the irritating material, and by constantly allowing the irritation to continue indefinitely the sense may become so blunted that the condition known as *chronic constipation* results.

791. NATURE OF FECES.—Feces consists mainly of: (1) the undigested and indigestible parts of the food; (2) substances resulting from the decomposition of food, as indol, skatol, fatty acids, etc.; (3) salts; (4) bile and other secretions; (5) enzymes; and (6) bacteria. The normal color of the feces is due largely to the bile, and when any obstruction in the liver ducts occur and the bile is absorbed instead of being poured into the

intestine, the stools are clay-colored. Abnormal conditions in any part of the digestive apparatus may be often determined by the nature of the feces.

Absorption

792. Where Absorption Takes Place.—It is thought that perhaps a small amount of such substances as alcohol, salts, and glucose may be absorbed from the stomach, but absorption takes place almost entirely from the intestines. The protein substances, glucose, etc., pass into the capillaries, and the fats into the lacteals of the villi that are contained in the mucous membrane of the small intestine. Formerly it was thought that very little absorption took place in the large intestine, but experiments conducted with the help of the X-rays have shown this not to be the case. However, to be absorbed from the large intestine, food must be digested, and when food is introduced into the colon via the rectum, by means of a rubber tube (as it often is when it cannot be taken by the mouth), it must be digested before it is administered, the large intestine not having the enzymes to promote digestion. Food introduced in this way, however, is not very completely absorbed.

793. Nature of Absorption.—Absorption is not, as was thought formerly, a simple physical process whereby the digested food material passes

by osmosis and diffusion from the intestine into the blood, but it consists in addition of more complex physiological processes. During absorption, the soaps and some of the fatty acids and glycerin are reconverted into fats and, until lately, it was thought that the amino-acids were resynthesized to proteins, but recent investigations have shown this not to be the case.

CHAPTER XIX

METABOLISM; HEAT REGULATION

Definition of Metabolism. Factors to which Metabolism is Due. Nature of Metabolic Changes. Object of Metabolism. Nature of Oxidation. Nature of Metabolism of the Various Food Substances. Food Requirement. Bad Effects that may be Caused by Ill-Regulated Diet. Where and how Heat is Produced in the Body. Distribution of Heat. Where and how Heat is Lost from the Body. Factors Regulating Involuntary Heat Regulation. Voluntary Methods of Regulating Heat. Effects of Cold, Tepid, and Hot Baths in Heat Regulation. Nature and Causes of Fever.

Metabolism[1]

794. DEFINITION.—By metabolism is meant the changes that occur in the products of digested food from the time they are absorbed until they are eliminated in the excretions.

795. FACTORS TO WHICH METABOLISM IS DUE.—The more important factors in promoting the metabolic changes are: (1) the oxygen absorbed from the lungs; (2) the enzymes that are present in nearly all the more active tissues of the body; (3) the internal secretions.

796. NATURE OF METABOLIC CHANGES.—The

[1] From the Greek *metabole*—a change.

chemical changes that occur in metabolism are many and various. Some of the more important are: (1) oxidation, *i. e.*, the union of oxygen with material in or of the cells and their breaking down into simpler substances with the production of heat and energy[1]; (2) the formation of acids and salts—much of the food acids, as that of fruit, and some of the acids formed in metabolism unite with alkaline substances to form salts.[2] *e. g.*, protein substances contain sulphur, and when the sulphur is set free, as a result of the decomposition of the protein, it unites with water and oxygen, thereby being converted into sulphuric acid (H_2SO_4). This is a corrosive poison, and did it not at once unite with alkalies present in the tissues and thus become a salt,[2] it would destroy the tissue cells with which it came in contact. (3) Glucose is changed to glycogen, a substance having the same chemical composition as dextrin. (4) Glycogen is reconverted into glucose, when the latter substance is needed in the tissues. (5) Glucose is changed to fat. (6) The cells select from the blood the special substances which they require for their growth and repair. (7) The

[1] See Glossary.

[2] All acids, however, are not neutralized—changed to salts—some are oxidized to CO_2 and H_2O; others are excreted in the urine, which gives human urine its characteristic acid reaction. In certain diseases, as diabetes, in which metabolism is defective, the organism may become so surcharged with acid that acid intoxication or poisoning results and, unless the condition is relieved, death ensues.

material thus selected is synthesized or built up. It will be noticed that these changes are of two kinds—breaking and building. The splitting processes are termed katabolism,[1] the building processes are termed anabolism.[2]

797. Object of Metabolism.—The two fundamental objects of metabolism are: (1) the building of the body tissues; (2) the production of heat and energy.

798. Nature of Oxidation.—Formerly it was thought that oxygen alone was the cause of the decomposition continually going on in the body, but increased knowledge of the nature and results of the oxidation occurring within the body has caused this idea to be abandoned. The present most generally accepted theory is that the inciting cause consists of ferments or enzymes contained within the tissues. These, it is thought, cause a gradual cleavage of the complex material in the tissues into simpler substances, which under the influence of other enzymes—termed oxidases—undergo a still further breaking down with the intake of oxygen.

Metabolism of the Various Food Substances

799. Carbohydrates.—The carbohydrates, it will be remembered, are changed to glucose by the process of digestion, and absorbed by the capil-

[1] From the Greek *kata*—down and *balto*—to throw.
[2] From the Greek *ana*—up and *balto*—to build or throw.

laries in the villi of the small intestine. After absorption the glucose is carried to the portal vein and thence to the liver, where the glucose molecules are put together with a loss of water, and so made into glycogen and as such stored in the liver,[1] or, if there is much, taken to the tissues and stored there. The reason for the change from glucose to glycogen is that glucose is a soluble substance and so could not be stored, but would remain constantly in the blood. This would be injurious, for the presence of glucose in the blood in abnormally large amounts is very irritating to the tissues. The normal quantity of glucose for the blood is about 0.1 to 0.15 per cent., and this amount, in health, it maintains constantly,[2] though it is continually giving glucose to the tissues to replace that oxidized there. That the blood can thus maintain a constant per cent. of glucose is due to the fact that as it parts with its supply the glycogen in the liver and tissues is reconverted into glucose.

800. Factors Governing the Action of the Liver on Glucose.—The conversion of glucose into glycogen and glycogen into glucose is controlled to some extent by nervous influences, but

[1] This process is known as dehydration. It is exactly the opposite of hydrolysis, the process by which starch and sugars are changed to glucose in digestion.

[2] The eating of large amounts of sugar, by providing more glucose than the liver can at the time change to glycogen, may temporarily surcharge the blood with glucose, but this will be eliminated in the urine. This is further described in paragraph 892.

how this control is maintained is unknown. It has been suggested that there is a *sugar center* which may be influenced by the amount of sugar in the blood, just as the respiratory center is influenced by the amount of carbon-dioxid in the blood. But, if this is the case, the way in which the center exerts its control is much more complicated and indirect than the action of the respiratory center. Recent investigations have tended to show that the nervous control may be at least partly exerted through the adrenalin glands, for their secretion, which is stimulated by nervous influence, seems to aid the glygogenic and glycolytic action of the liver.

801. Utilization of Glucose in the Tissues. —The powers controlling the utilization of the glucose in the tissues are also but imperfectly understood beyond that essential factors are: Certain of the internal secretions, especially that of the pancreas,[1] and enzymes. Some enzymes promote oxidation and some a cleavage whereby the molecules are split into simpler ones which are more easily oxidized. As the result of these processes lactic and other acids are formed and most of these are gradually oxidized to carbon-dioxid and water. If the supply of glucose exceeds the body's fuel requirement and glycogen-storing

[1] One reason for this supposition is that if a puncture is made in a certain part of the medulla oblongata, the metabolism of glucose is interfered with and glucose appears in the urine.

capacity, the surplus will be synthesized to fatty tissue.

802–803. METABOLISM OF FATS.—It will be remembered that the soaps into which fats are changed in digestion are, during absorption, reconverted into fat, which is carried to the thoracic duct and thence emptied into the left innominate vein, thus entering the blood. The fat remains circulating in the blood for a considerable time, being slowly picked out as required by tissues which can use it in their metabolic processes. Within these tissues it is eventually oxidized to $C\ O_2$ and H_2O. Knowledge of the intermediate stages of fat metabolism is still limited. If they are defective, diacetic acid and acetone may be formed.

804. FUNCTION OF FATS.—(1) By their oxidation they yield heat and energy; (2) when stored in the tissues (*a*) they supply substance for oxidation when there is a lack of food, either because of deficiency of food or in disease, and thus protect the protein parts of the body from oxidation. The reason why this is of special value will be discussed under protein metabolism, paragraph 807. (*b*) The fat under the skin prevents the too rapid radiation of heat, and thus helps to keep the body warm.

805. SOURCE OF BODY FAT.—The main sources of body fat are the fat and the carbohydrate foods.

806. CAUSE OF EXCESS STORAGE OF FATS—

OBESITY.—A common cause of obesity is eating a larger amount of food than is necessary for the body requirements (paragraph 811) especially fat and carbohydrate foods. Other causes are: the leading of a sedentary life, lack of muscular exercise, absence of worry, and all other conditions not calling for muscular or nervous energy. Some individuals store fat much more easily than others. This is thought to be due to a difference in the capacity to oxidize food-products. This capacity is greater in youth than in old age, and at all times some people possess it to a much greater extent than others.

807. METABOLISM OF PROTEINS.—As stated in Chapter XVIII, the proteins are broken into peptones, polypeptids, and amino-acids as the result of digestion. As these substances have not been found to any extent in the blood, it was thought that they must be synthesized into blood proteins—during absorption. Recent discoveries, however, have given rise to the opinion that the amino-acids are absorbed into the blood as amino-acids and pass in this form to the tissues, where, during the years of growth, as much as required is used for tissue building and, both in youth and after growth has ceased, to replace material that has been oxidized. The amino-acids not needed for these purposes undergo cleavage in which the nitrogen is split off in combination with hydrogen in the form of ammonia. This, by uniting with carbon-dioxid and undergoing other chemical

changes, is converted into urea, which is absorbed and carried by the blood to the kidneys for elimination in the urine. Formerly, it was thought that urea was formed only in the liver, but now it is considered probable that the change occurs also in the tissues. When the ammonia is split from the the amino-acid molecule, the remaining hydrogen and the carbon and oxygen are left in the form of acids which, for the most part, are oxidized to carbon-dioxid and water. The proteins of cell nuclei, by katabolism, give rise to phosphoric acid and substances known as *purin bodies*, of which the final decomposition product is uric acid.

808. NITROGEN EQUILIBRIUM.—The body is said to be in nitrogen equilibrium when the amount of nitrogen in the urine is the same as that taken in food. Protein molecules contain 16 per cent. nitrogen.[1]

809. FUNCTION OF PROTEIN.—The principal purpose of the food proteins, except certain simple ones such as gelatin and the extractives, is to build muscular tissue, and the body is entirely dependent upon proteins for this purpose, for as the fats and the carbohydrates do not contain nitrogen, they are unable to do so. The proteins also, by virtue of their C O H molecules, perform the same offices as the carbohydrates and fats and yield heat and energy, and may even be built into adi-

[1] Students who wish to know more about nitrogen equilibrium are referred to *Text-Book of Physiology*, Chapter XLVII. Howell.

pose tissue. Gelatin and extractives, though they contain nitrogen, are lacking in some of the essentials for tissue building, and therefore serve only for the same purposes as carbohydrates. The nitrogen is split off, as in the case of the other proteins, in the liver and excreted in the urine.

810. HEAT VALUE[1] OF THE FOOD-STUFFS.—As the result of many experiments, it has been found that every gram of protein yields to the body about four calories of heat; every gram of carbohydrate four calories; every gram of fat nine calories.

811. FOOD REQUIREMENT.—The amount of food actually required to provide sufficient heat to maintain the normal body temperature, to yield the necessary amount of energy, and build and repair body tissue, will depend upon the individual's occupation, size, sex, and the climate. The more muscular force an individual's occupation entails, the greater amount of food he will require; a large person requires more food than a small one, the greater amount of tissue resulting in more internal work; a tall, thin person will need

[1] The intensity of heat is measured by the clinical thermometer and recorded in degrees; the amount of heat is measured with the calorimeter and recorded in calories. There are two kinds of calories. A small calory is the amount of heat required to raise the temperature of one gram of water 1 degree C; a large calory is that required to raise the temperature of 1 kilogram (1000 grams) of water 1 degree C. It is the large calory that is referred to in physiology. The difference between the intensity and the amount of heat can be illustrated as follows: if boiling water is poured into a cup and a quart pitcher, the temperature in both vessels is, for the time being, the same; but there is a larger amount of heat in the pitcher.

more than a short, stout person of equal weight, on account of the larger skin surface exposed for the radiation of heat. Women, being as a rule smaller than men and expending less energy in their movements, require less food than men—about four-fifths of a man's rations. Children need food for growth as well as for the repair of tissue, and expend comparatively more energy than adults, and therefore require more food in proportion to their weight than the latter. The average comparative amount of food required by children can be seen in the following table:

A child	14	to	16	years	requires	0.8	the food of a man doing moderate work							
"	"	10	"	13	"	"	0.6	"	"	"	"	"	"	"	"
"	"	6	"	9	"	"	0.5	"	"	"	"	"	"	"	"
"	"	3	"	5	"	"	0.4	"	"	"	"	"	"	"	"
"	"	2			"	"	0.3	"	"	"	"	"	"	"	"

By investigating the quantity of food eaten by a large number of people in good health and employed in various occupations, and by careful quantitative analysis of all the excreta, thus determining the amount of metabolism going on in the body, it has been estimated that a man weighing about 140 lbs. needs sufficient food during twenty-four hours to yield:

	Calories.
"*When not doing muscular work*	2450
" *doing light muscular work (sedentary)*	2700
" " " *to moderate muscular work*	3050
" " *moderate muscular work*	3400
" " *very hard* " "	5500 "[1]

[1] *Circular No. 46.* 1906. United States Department of Agriculture, Office of Experiment Station.

812. Comparative Average Proportion of Proteids, Fats, etc., Used.—The comparative proportion in which the food principles are used is about as follows: sufficient protein food is used to give one-fifth the number of calories required; sufficient fat to yield a like number of calories; sufficient carbohydrates to make up the remaining three-fifths of the calories. Thus, to get 2450 calories sufficient protein food is used to give 490 calories, and as each gram of protein yields 4 calories this would mean 122.27 grams of protein. Sufficient fat is used to yield 490 calories, and as each gram of fat gives 9 calories, this would mean about 54 grams of fat. Enough carbohydrate is used to yield 1470 calories, and as each gram of carbohydrate gives 4 calories this would mean 367.2 grams of carbohydrates. A table giving the relative amount of protein fats and carbohydrate in a few typical foods will be found at the end of the glossary.

813. Bad Effects of too Much and too Little Food.—The continual indulging in food much in excess of the body requirements favors the formation of excessive adipose tissue and is conducive to disease because it overworks the secretory and excretory organs, and, in the case of proteins, overloads the system with the products of intestinal putrefaction. Excessive quantities of carbohydrates are the source of flatulence due to the fermentation of these food-stuffs; also too much fat is thought to retard the secretion of the

gastric juice and so interfere with digestion. On the other hand, a lack of nutritious food weakens the body's natural power of resistance to disease.

Heat Production

As has been stated repeatedly in the preceding pages, one of the most important uses of food is the production of heat.

814. How Heat is Produced.—The heat produced in the body arises principally from such of the chemical changes going on in the tissues as are associated with oxidation. Some of the minor sources of heat are friction, *e. g.*, that caused by the movements of the muscles, circulation of the blood, etc., and the ingestion of warm food.

815. Where Heat is Produced.—After the circulation of the blood was described by Harvey in 1628, physiologists taught that the body heat was the result of friction due to the circulation of the blood and the action of the heart and blood-vessels. Later, when the signification of respiration became better understood, it was taught that heat was created in the lungs and distributed through the system by means of the blood. But modern physiologists have proven conclusively that heat is developed in all the living tissues of the body, but is produced to a greater extent in those tissues in which metabolism is most active, as the muscles and the secreting glands, especially the liver.

816. Distribution of Heat.—Though a greater amount of heat is formed in some tissues than in others, the temperature of all the internal parts of the body is about alike. This is due to the uniform temperature which the blood maintains by circulating rapidly from vessels situated in tissues where oxidation is greatest to parts exposed to radiation and evaporation, thus balancing its gain and loss of heat.

817. Loss of Heat.—In health the human body maintains a constant temperature between 98° and 99° F. In order to do this, as heat is being continually created within the body, there must be an equally constant loss of heat. This loss is effected in several ways: (1) by radiation and conduction from the external surface of the body; (2) by constant evaporation of water from the same part[1]; (3) by taking into the lungs colder air than that given out; (4) by the loss of warm substances from the body, as the urine and feces; (5) by the ingestion of cold food and drink. The effectiveness of these different channels for the loss of heat varies greatly, as can be seen by the following table:

By radiation and conduction from skin	73.0%
By evaporation from skin	14.5%
By expired air (vaporization of water from lungs)	7.2%
" " " (warming of air)	3.5%
" urine and feces	1.8%

[1] In order that water may evaporate, heat is required—about 0.5 calories for each gram of water that is evaporated. The heat necessary for the evaporation of sweat is taken from the body.

The loss of heat due to the ingestion of cold food and drink is so small that it need hardly be counted.

Certain conditions, such as the external temperature, may cause considerable difference in the per cents. given above, especially in the radiation and evaporation; *e. g.*, a high external temperature will diminish the loss of heat by radiation and increase that by evaporation, owing to the greater production of sweat.

From the figures in the above table it will be seen that the skin is the principal factor in getting rid of body heat. That it is so is due: (1) to the large surface offered for radiation, conduction, and evaporation; (2) to the large amount of blood which it contains.

Heat Regulation

Heat regulation may be said to be effected by involuntary and voluntary means.

818. Influence of the Nervous System on Involuntary Heat Regulation.—In health the loss and production of heat are so evenly balanced that the temperature of the body, as previously stated, remains almost constantly between 98° and 99° F. This is largely due to the control exerted by the nervous system, which is one of the principal factors in regulating the amount of heat lost through the skin and lungs, and of the degree of metabolism taking place in the tissues.

819. Influence of the Nervous System in Heat Regulation by the Skin.—The regulation of body heat by the skin is effected by means of the sensory nerves of the skin, the sweat nerves, and the vaso-motor nerves. Thus, when the external temperature is warmer than usual, the nerve-endings in the skin which respond to heat are stimulated, and impulses passing from these sensory nerves to the centers controlling the motor nerves of the sweat glands, the production of sweat is increased, and the greater the amount of perspiration the greater the amount of heat that will be taken from the body to vaporize the water. If there is much humidity in the air, however, the evaporation of water is hindered and the production of heat in the body may become excessive. This is one of the most common causes of the condition known as *heat prostration* or *sunstroke*. In addition to stimulating the sweat nerves, the stimulus from the sensory nerves affected by heat causes depression of the vaso-constrictors of the skin arterioles, in consequence of which these vessels become dilated and an increased supply of blood comes to the surface, where it loses some of its heat by radiation. On the other hand, when the external temperature is cold, the nerve-endings in the skin which react to cold are stimulated and carry impulses to the vaso-motor centers, in consequence of which the vaso-constrictors are stimulated, and consequently the skin blood-vessels become contracted and the blood is driven

from the skin, thus lessening the amount of heat lost by radiation.

820. INFLUENCE OF THE NERVOUS SYSTEM IN HEAT REGULATION BY THE RESPIRATION.—The stimulation of the cold nerves of the skin influences the respiratory centers, thereby causing an increase in the rate of respiration, and consequently augmenting the loss of heat to some extent. In man, however, the respiration plays only a small part in heat regulation, but in animals covered with a coat of hair, which interferes with the loss of heat through the skin, respiration is a very important factor.

821. INFLUENCE OF THE NERVOUS SYSTEM IN CONTROLLING HEAT REGULATION BY METABOLISM. —How the nervous system influences metabolism has not yet been decided. Some physiologists consider that there are special nerves and heat centers which, influenced by the temperature of the blood, augment or inhibit the rate of metabolism; but many others do not believe in the existence of special heat centers and think that the variations in heat production occur simply as the result of reflex excitation of the motor nerve-fibers supplying the muscles which, when stimulated by cold, cause a condition of greater contraction in those organs and, in consequence, an intensification of the oxidation taking place in them. The vaso-motor system also influences metabolism to some extent, for the process is accelerated when, under the influence of cold,

the blood is driven, as described in the preceding paragraph, to the interior of the body and inhibited when, under the influence of heat, a greater amount of heat goes to the surface of the body.

822. Voluntary Methods of Controlling Heat Regulation.—The usual voluntary means taken to control heat production and elimination are: the use of suitable clothing; regulation of muscular exercise and diet; use of cold and hot baths.

823. Clothing.—Clothing serves to protect the body against cold by diminishing the loss of heat from the skin by radiation and evaporation. The properties to be considered in clothing with regard to heat regulation are: whether it is loosely or tightly woven, its thickness, and to a slight extent whether it is of light or dark color. A fairly loosely woven fabric will be warmer than a tightly woven one, because the loosely woven one is capable of holding considerable air in its meshes, and air, being a poor conductor of heat, will prevent heat radiation. Wool, silk, linen, and cotton will have about the same heat value if they are equally thick and equally porous. Wool, the texture of the materials being the same, may have a slight advantage over the silk, linen, etc., in retaining heat, in that evaporation of moisture takes place more slowly from wool than from the other fabrics. Thin, very porous material used as clothing helps to keep the body cool, because it allows the air to penetrate to the skin, and thus

facilitates the evaporation of sweat. Evaporation of absorbed perspiration takes place more quickly from cotton and linen than from woolen material, and they are usually of lighter weight, therefore they provide a cooler form of clothing. Dark-colored clothing absorbs heat to some extent, and therefore is somewhat warmer than white or light fabrics.

824. Regulation of Heat by Muscular Movement.—Muscular contractions are attended by a marked liberation of heat, therefore muscular activity is a frequently used means of counteracting the effect of external cold. On the other hand, in hot weather the tendency is to move slowly and as little as possible. That the body temperature does not rise to any marked extent as the result of muscular activity in hot weather is due to the other phenomena attendant upon activity, viz., the dilation of the cutaneous blood-vessels and consequent flow of blood to the surface, and to the increased amount of perspiration.

825. Effect of Baths in Heat Regulation —Cold Baths.—The primary physiological action of a cold bath is to contract the cutaneous blood-vessels and thus drive the blood to the internal organs and increase heat production; but if the individual remains only a few minutes in the bath, when he leaves it the hot blood comes to the surface and there is an accelerated circulation of blood through the skin whereby an increased quantity of blood is exposed to the cooling in-

fluences that act upon the surface of the body, thus increasing heat elimination. This constitutes the so-called reaction. A cold bath continued for some time will, if it does not produce shivering, lower the temperature of the muscles lying beneath the skin as well as that of the skin itself, and thus check the heat-producing processes that are active in the muscles. If shivering is produced the consequent muscular contraction and constriction of blood-vessels induce a very decided increase in metabolism and heat-production. It is to avert this condition that friction is applied during cold baths given in fever. The friction by irritating the sensory nerves of the skin causes dilation of the superficial blood-vessels and the flow of hot blood to the surface of the body, thus minimizing the sensation of cold and preventing shivering. Cold baths, when properly administered, stimulate the nervous system and thus improve muscular tonicity, including the muscle of the heart and blood-vessels; in this way the circulation is improved and heat elimination favored.

826. A Tepid Bath.—A bath of about 95° F., by dilating the arterioles of the skin thus causing the blood to come to the surface, and increasing loss of heat by radiation, will lower the body temperature, and the reduction will be greater if the tepid bath is followed by a cold one.

827. A Hot Bath.—A bath above the temperature of the body, by preventing radiation of heat from the surface of the body, will induce a rise of

temperature. If, however, the individual remains in the bath only a short time this effect may be counteracted by the increased perspiration and loss of heat by radiation that will follow.

Fever or Pyrexia

828. CHARACTERISTICS.—Fever is an abnormal condition, characterized by elevated temperature, quickened respiration and circulation, faulty secretions, and increased tissue waste. It is dependent upon a perversion of the physiological processes whereby the generation and loss of heat are so balanced as to maintain a uniform temperature.

829. CAUSE.—The exact cause of fever is unknown. As has been previously stated, some physiologists believe that there is a heat-regulating center which controls the production and elimination of heat, and those who believe in such a center think that fever may be due to disturbance of this center by toxic substances circulating in the blood, or other abnormal conditions.

830. ORIGIN OF TOXINS.—The toxic substances producing the thermogenic disturbances may owe their origin to bacteria, as in the infectious diseases; to faulty metabolism, as in gout, diabetes, etc.; or to mechanic, thermic, or chemical injury to the tissues.

831. FEVER A PROTECTIVE MEASURE.—Though fever is an abnormal condition it is now

thought to be one of nature's protective measures, for the body, especially when pyrexia is due to bacterial invasion, seems to be able to fight the poison better when its temperature is somewhat elevated. This is one reason why antipyretics are not used, unless the temperature remains persistently high, or the elevation is extreme. Of course, in either of the above instances measures must be taken to reduce the temperature, or changes will be produced in the tissues of the body that may cause death.

832. BATHS IN PYREXIA.—The use of baths in febrile conditions is usually not so much to lower the temperature as for their effect on the circulatory, respiratory, and nervous systems. If these are favorably affected the temperature, probably, will be somewhat reduced.

CHAPTER XX

ELIMINATION

The Urinary System

Names of the Excretory Organs. Nature of the Excreta Eliminated through these Organs. Name, Location, Structure, and Function of Each of the Organs comprising the Urinary System. Nature of the Processes of Secretion and Elimination of Urine. Quantity of Urine Voided in Twenty-four Hours. Physical Properties of Urine. Normal and Abnormal Constituents of Urine.

833. It has been stated repeatedly in the preceding chapters that the life processes of the body are attended with the formation of waste products, which must be removed from the system, many of them being of a toxic nature. This waste matter is spoken of as *excreta*, the process by which it is discharged from the body as *excretion* or *elimination*, and the organs through which the elimination takes place as the *excretory organs*.

834. The names of the excretory organs are:

1. The organs of the urinary system { 2 kidneys, 2 ureters, 1 bladder, 1 urethra

2. Lungs
3. Intestines
4. Liver
5. Skin

The waste matter discharged through each of these organs is as follows:

835. (1) **By the urinary organs:** practically all of the protein waste[1]—both that of metabolized food protein and body tissue, nearly all the salts,[2] about four-fifths of the water that is excreted,[3] and a small amount of carbon-dioxide.

836. (2) **By the lungs:** water and nearly all the carbon-dioxide formed by oxidation. In diseased conditions of the kidneys a small amount of urea is sometimes removed by the lungs, and is easily detected by the odor it imparts to the breath.

837. (3) **The liver** eliminates the bile which contains waste products secreted from the blood and those formed in the liver.

838. (4) **The intestines** eliminate not only

[1] This consists principally of such substances as urea, uric acid, creatinin, xanthin, etc.

[2] The salts excreted represent those taken in food and not utilized; those liberated in the breaking down of body tissue; those formed by the neutralization of the acids resulting from the metabolism of food products and body tissue, as described in paragraph 796.

[3] When the skin is very active less water is excreted by the kidneys. The water eliminated from the system consists of that ingested in both liquid and solid food, and that formed in the body as the result of chemical reactions.

undigested and unabsorbed food material, as described in paragraph 790, but some salts, and, when the kidneys are diseased, some of the waste of protein metabolism. These last-named substances pass from the blood as it flows through the capillaries in the intestinal walls.

839. (5) **The skin** eliminates water, ordinarily about one quart[1] in twenty-four hours; a small amount of salts and protein waste. The amount of protein excreted by the skin is increased when free perspiration is induced, especially when the kidneys are not functioning properly.

Of these organs, those comprising the urinary system are the only ones concerned solely in ridding the body of waste products.

Anatomy and Function of the Urinary System

The urinary system consists, as previously stated, of the two kidneys, the two ureters, the bladder, and the urethra.

The Kidneys

840. NATURE AND LOCATION.—The kidneys are two compound tubular glands situated in the posterior part of the lumbar region of the abdomen, one on either side of the spinal column, behind the peritoneum. They correspond in position to the two last dorsal and two upper lumbar

[1] This quantity is greatly increased when the body becomes over-heated, and the amount then eliminated by the kidneys is correspondingly diminished.

vertebræ. The right kidney is slightly below the left in consequence of the position of the liver.

841. How Retained in Place.—The kidneys are retained in place by the fat in which they are imbedded, by the peritoneum which covers their anterior surface, and by their ureters and large blood-vessels. A diminution of the fat surrounding the kidneys is sometimes the cause of their becoming loosened from their position, a condition that is known as *floating kidney*.

842. Shape.—The kidneys are bean-shaped and lie with their concave side toward the spine and their convex side directed outward. Near the center of the concave side is a notch or depression called the hilum, which is the passage-way for the ureter and for the blood and lymph-vessels, and for the nerves going to and from the kidneys.

843. Size.—The kidneys are about 4 inches long, 2½ inches broad, and 1½ inches thick, and each one weighs about 4½ ounces (135 grams).

844. Names of the Various Parts of Each Kidney.—Each kidney may be said to consist of:

(1) A capsule
(2) A cortex — Malpighian[1] bodies — Malpighian capsule; Glomerulus[2]
(3) A medullary portion — Pyramids of collecting tubes
(4) A pelvis — Calyces or cups

[1] Named after Malpighi, a celebrated anatomist.
[2] From the Latin *glomerulus*—a ball.

845. STRUCTURE.—Each kidney may be said to consist of a central cavity surrounded, except at the hilum, by kidney substance. The cavity which is called the pelvis is in reality the expanded portion of the ureter—the tube connecting the kidney with the bladder. The kidney substance consists principally of a vast number of minute tubes known as the urinary or uriniferous tubes or tubules and blood-vessels held together with areolar tissue. The outer portion of this substance is more compact than that immediately surrounding the pelvis and is known as the cortex[1]; the less dense portion is called the medulla.[2]

846. THE URINIFEROUS TUBES.— The uriniferous tubes[3] commence at the cortical portion of the kidney as hollow globes, dented in the center, as in Fig. 121, called the *Malpighian capsules*. The tubes at their connection with the capsules are very convoluted (see Fig. 121), but they finally pass as straight tubes through the medullary portion of the kidney and terminate by open mouths in the cup-like processes of the pelvis known as the *calyces*. The tubes are bound together in cone-shaped bundles called *pyramids*. There are about a dozen such pyramids in a human kidney, each one comprising innumerable tubes.

[1] From the Latin *cortex*—bark.

[2] See foot-note page 166.

[3] "It has been estimated that each kidney contains about half a million capsules and fifte[illegible] tubing."—GERRISH.

FIG. 121.—Diagram of the structure of a lobe of the kidney. The lobe is seen in vertical section, the cortex being marked off from the medulla. Four medullary rays encroach upon the cortex. At the left is shown the course of a single, continuous series of tubes—the straight and spiral tubes appearing in the medullary ray, the straight, looped, and excretory in the medulla proper, the capsule, neck, convoluted, irregular, and arched in the cortex proper. Next is seen the labyrinth, composed of a mass of tubes in the cortex, with a medullary ray for a centre. Equidistant from the ray on each side is a broken red line, marking the position of an interlobular artery. The parts between these lines constitute a lobule. Farther to the right is an interlobular artery, giving off lateral branches (afferent vessels), each of which ends in a tuft of capillaries, from which the blood is collected by an efferent vessel. The uppermost of the tufts is shown enclosed in a capsule. On the right of the interlobular artery the efferent vessels break up into a capillary network which surrounds the (unrepresented) tubes in the cortex and ray. The lowest efferent sends vertical vessels also into the medulla. On the right the interlobular vein is seen gathering the blood from all the parts supplied by the interlobular artery. A branch of the venal artery courses upward between cortex and medulla, and forms an arch (here broken) over the base of the medulla. From it the interlobular arteries pass upward into the cortex, and straight branches go downward into the medulla, supplying its structure, and ending at the apex in the capillaries. From the last the radicles of the venal vein arise, and accompany the straight arteries to the base of the medulla, where a venous arch is formed, continuous with which is the vena comes of the entering artery. The calyx embraces the apex of the medullary pyramid. It is lined with epithelium, which continues from it over the apex, the latter being perforated with the many apertures of excretory tubes. (Gerrish.)

847. Malpighian Bodies.—In the dented portion of each Malpighian capsule there is a tuft of capillary blood-vessels called a glomerulus. The capsule and blood-vessel combined are known as a Malpighian body. Each body is about $\frac{1}{120}$ of an inch in diameter. The walls of the Malpighian capsule as well as those of the glomerulus are exceedingly thin and closely adherent, thus facilitating the passage of substances from the blood into the tubes.

848. The Kidney Capsule.—Each kidney is covered by a tough fibrous membrane termed the capsule. The inner surface of which is slightly attached, by means of fine fibers of areolar tissue and minute blood-vessels, to the substance of the kidney. At the hilum of the kidney this capsule becomes continuous with the external coat of the ureter.

849. Blood Supply of the Kidney.—The kidney is plentifully supplied with blood by the renal artery which, entering through the hilum, divides into several branches. These branches give off subdivisions that penetrate the kidney substance and carry nutriment to the tissues. The branches passing to the cortex give off small side-twigs which pass to the Malpighian bodies. One of these small afferent (carrying-to) vessels enters the dented portion of each capsule, and breaks up into a dense convoluted capillary plexus —the glomerulus—which is ultimately gathered up again into an efferent (carrying-from) vessel,

that leaves the capsule near the point at which the afferent vessel entered. After leaving the capsule the efferent vessel breaks up once more into capillaries and forms a plexus over the surface of the tubules. Finally the capillaries unite to form small veins, and these joining the veins which hold the blood returning from the substance of the kidneys unite to form the renal vein which, leaving the kidney at the hilum, passes to the inferior vena cava.

850. PURPOSES OF THE DIFFERENT SETS OF CAPILLARIES.—It is from the capillaries of the glomeruli and those around the convoluted portion of the tubules that the passage of waste matter from the blood to the tubes takes place (see paragraphs 847 and 849); the other branches of the renal artery serving to hold the blood that carries the necessary nutriment to the substance of the kidney.

851. NERVES AND LYMPHATICS.—The kidneys are liberally supplied with nerves and with lymphatics. The nerves are derived from both the cerebro-spinal and the sympathetic systems, many of them are vaso-motor nerves, and as these regulate the contraction and relaxation of the blood-vessels the blood pressure in the kidneys is much influenced by their action.

852. FUNCTION OF THE KIDNEYS.—The function of the kidneys is to excrete waste matter resulting from metabolism, more especially the protein waste, water, and salts, and foreign mat-

ter such as poisons, either those taken into the body or those formed within the body—auto-intoxicants.

853. Nature of Process.—The exact nature of the process by which the kidneys rid the body of these substances is not known beyond that it is not entirely a matter of simple filtration and diffusion, as was thought formerly, but due also to the part played by the epithelial cells lining the convoluted portion of the tubules which seem to make selection of the matter that is to pass into the tubules. This activity of the cells is spoken of as secretion, and can be compared to the secretory processes carried on by the secretory cells of the stomach, pancreas, and intestines, by which they pick out from the blood the substances they require for the manufacture of the digestive juices.

854. Excretion of Water and Salts.—The diffusion of water and the salts which are in solution in the water, takes place chiefly, it is thought, in the Malpighian bodies. These, it will be remembered, each consist of a knot of minute capillaries called a glomerulus, surrounded by a portion of a urinary tube. The blood in the glomeruli, owing largely to the small caliber of the vessels and their convoluted arrangement, is under considerable pressure[1]; in the urinary

[1] The degree of pressure is dependent chiefly upon: (1) the amount of blood passing through the vessels, (2) the nature of the heart-beat, (3) the action of the vaso-motor apparatus.

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tubules, on the other hand, as the urine never remains therein but passes at once into the pelvis of the kidney and thence into the ureter, the pressure is at zero.[1] It is therefore only natural, the walls of blood-vessels and tubules being very thin, that osmosis from the vessels into the tubes should take place.

855. To recapitulate: the water and salts are thought to pass into the urinary tubules from the glomeruli by osmosis, and the protein waste from the capillary plexus on the walls of the convoluted portion of the tubules by secretion.

856. Secretion of Protein Substances.—The epithelial cells lining the convoluted portion of the urinary tubules are different in structure from those of any other part of the tubes and similar to many of the secretion cells in the glandular organs. For this and other reasons which need not be entered into here, it is thought that the separation of the protein waste substances from the blood is the special function of these cells. The manner in which the plexus of capillaries arising from the efferent vessels of the glomeruli adhere to the walls of the convoluted portion of the tubules (see paragraph 849) brings these cells into close relation with the blood which, owing to the small caliber and tortuous arrangement of the capillaries, flows, as in the glomeruli, very slowly and under considerable pressure.

[1] Pressure is said to be at zero when no pressure is exerted, which is of cour[illegible] if the tubes are empty.

The Ureters

857. FUNCTION.—The ureters serve to connect the kidneys with the urinary bladder; they thus afford a channel for the urine from the former organs to the latter.

858. SIZE.—Each ureter consists of a distended portion called the pelvis, which is contained within the kidney, and a duct. The duct is about the diameter of a goose-quill and from 12 to 18 inches (300 to 400 *mm.*) long.

859. STRUCTURE.—The walls of the ureters consist of three coats—an outer elastic coat, a middle muscular, and an inner mucous lining.

The Urinary Bladder

860. FUNCTION.—The urinary bladder is a musculo-membranous sac which forms a reservoir for the urine in the intervals of its expulsion from the body.

861. LOCATION.—The bladder is situated in the pelvic cavity behind the pubes, in front of (in the female) the anterior wall of the vagina and neck of the uterus; in front of the rectum, in the male. In infancy the bladder extends into the hypogastric region of the abdomen; in the adult, when empty, it is contracted and lies low in the pelvis, and it never rises above the pelvis unless over-distended. In the latter case it may extend nearly as high as the umbilicus. It is freely movable but is retained in position by several

ligaments, some of which are formed by folds of peritoneum and some of fascia extending from the walls of the rectum, uterus, etc.

862. DIVISIONS—SIZE.—The bladder is, for purposes of description, usually divided into the fundus or body and the cervix or neck, the latter being the constricted portion which is continuous with the urethra. When moderately distended the fundus measures about five inches in length and three inches across, and holds about one pint.

863. STRUCTURE.—The wall of the upper part of the bladder consists of four coats, and that of the lower portion of three; the outer serous coat, which is derived from the peritoneum, being present only on the upper extremity of the fundus. The other coats are: (1) the muscular, (2) the areolar or submucous, (3) the mucous. The muscular coat is arranged in three layers, the fibers of the outer and inner layer having a longitudinal direction, and those of the middle a circular. The circular layer is especially developed in the cervix of the bladder and thus forms a sphincter which serves to control the passage of urine.

864. BLOOD-VESSELS AND NERVES.—The bladder is well provided with blood- and lymph-vessels and with nerves. The latter are derived from both the sympathetic and cerebro-spinal systems.

The Urethra

865. NATURE AND SIZE.—The urethra is a narrow membranous canal about one and one-

half inches in length in the female and eight or nine in the male. Its normal diameter is about one-quarter of an inch, but it is capable of considerable dilatation.

866. LOCATION.—The urethra extends from the neck of the bladder to the external orifice, which is known as the *meatus urinarius*. In the female it is situated beneath the symphysis pubis, and embedded in the anterior wall of the vagina. Its direction is obliquely downward and forward, its course being slightly curved, with the concavity directed forward and upward. It is important to remember the direction of the urethra, as it must be followed when introducing a catheter into the bladder. The external orifice of the urethra, the meatus urinarius, is situated between the clitoris and the opening of the vagina (see Fig. 134, page 497).

867. STRUCTURE.—The wall of the urethra consists of three coats: an outer muscular coat, a submucous, and a mucous. The last named is continuous with that of the bladder. The submucous coat contains a network of large veins.

Micturition

868. Micturition is the act by which the urine is expelled from the bladder. It occurs, normally, as the result of irritation, due to the accumulation of urine, which stimulates the muscular walls of the bladder to contraction. This contraction

causes the dilatation of the sphincter muscle and ejection of the urine. The action itself is involuntary, but it can be controlled by voluntary effort.

869. CAUSES OF INVOLUNTARY MICTURITION. —Involuntary micturition may occur as the result of lack of consciousness; as the result of spinal injury involving the nerve-centers that send impulses to the bladder; in consequence of lack of "tone" in the muscular walls; or as the result of abnormal irritation.

870. RETENTION.—Retention, or failure to pass urine from the bladder, may be due to: (1) some obstruction in the urethra or neck of the bladder, (2) nervous contraction of the urethra, (3) dulling of the senses so that there is no desire to pass urine.

871. RETENTION WITH OVERFLOW. — The bladder may become so fully distended that there is a more or less constant overflow or voiding of small amounts of urine, but the walls of the bladder are temporarily paralyzed and therefore do not contract sufficiently to empty the organ.

The Urine

872. QUANTITY.—The average amount of urine voided in 24 hours by a healthy adult is about 40 to 50 ounces; by a child of

2 to 5 years, 15 to 25 ounces
5 to 9 years, 25 to 35 ounces
9 to [illegible] years, 35 to 40 ounces

Causes likely to diminish the quantity of urine are: the consumption of a small amount of liquids, free perspiration, high fever, diarrhea, vomiting, and some disease of the kidneys.

Causes likely to increase the quantity of urine are: the ingestion of a large amount of liquids; nervousness; the action of diuretics; certain diseases, more especially diabetes mellitus, diabetes insipidus, and hysteria.

873. Physical Properties.—Normal urine is a transparent, yellowish or light amber-colored liquid, with a characteristic odor, a slightly acid reaction, and a specific gravity of 1012 to 1030, 1020 being the average.

874. Specific Gravity.—By specific gravity is meant the weight of the urine as compared with that of distilled water at 60° F., the weight of the water being 1000. The specific gravity indicates the relative proportion of solid matter in the urine, and when it is much increased the presence of abnormal constituents is often suspected; but an increase or decrease in the amount of urine, even from normal causes, will influence the specific gravity, since it will be lower if a large amount of water is secreted by the kidneys and higher if the urine is less dilute.

875. Causes of Change of Color in Urine.—The conditions causing variations in the quantity of urine are also likely to change its color. When its secretion is diminished it is generally highly colored, the amount of solids present being

comparatively large. When its secretion is abnormally increased it is more dilute and is usually of a pale straw color, except when the increase is due to diabetes mellitus, in which case the color is darker, owing to the presence of sugar. Other causes of changes of color are: decomposition of the solid constituents of the urine; the presence of abnormal substances; large doses of certain drugs, such as iodoform, salol, guaiacol, and carbolic, which make the urine olive green; logwood, which makes it blood-red; rhubarb and senna, which cause a bright orange color; methylene blue, which makes it a bluish-green shade.

876. Reaction.—The acid reaction characteristic of the urine of the majority of human beings is due to the quantity of foods they eat of which the waste products are acid. After a diet consisting solely of carbohydrates the urine will be alkaline, as is the urine of herbivorous animals, because of the presence of ashes of plant foods which contain a large amount of alkaline matter. If human urine is allowed to stand for any length of time after being voided, it will become alkaline, unless it be kept sterile, because bacteria will break up its protein constituents into ammonia and other alkaline substances. This same kind of decomposition may take place within the body in certain diseased conditions of the urinary organs, especially cystitis, and under such circumstances the urine will be alkaline when voided.

877. Composition of Urine.—The urine nor-

mally consists principally of water, holding in solution certain organic substances, such as urea, urates, creatinin, xanthin, etc.—which are products of the oxidation of protein substances,—saline substances, and pigments. Also there may be, even in health, various other matters present derived from unusual articles of food, or from drugs that have been taken into the system. In diseased conditions, especially in disturbances of metabolism or of kidneys, other substances, which will be described later, may be present. Therefore the condition of the urine is often of value in determining the nature and progress of a disease, even when it does not affect the urinary system.

878. Urea.—Urea, which constitutes nearly one-half of the solid constituents of urine, is formed in the body, largely in the liver, by the oxidation of protein substances derived from food, and, to some extent, from body tissue. Normally, an adult voids between 20 and 30 grams (about one ounce) daily, but the quantity will be increased, by a diet containing a large amount of protein food, by strenuous exercise, hot baths, fever in its early stages, and a few diseases. It will be diminished, when only a small amount of protein food is eaten, by free perspiration, excessive vomiting, and a few diseases, especially those which affect the kidneys and interfere with elimination.

879. Uric Acid.—Uric acid, next to urea, is the medium by which the largest quantity of nitrogen is excreted from the body. It is thought

that it is formed in the tissues, especially in the liver, from the nuclei of cells. Uric acid when pure is colorless, but it is not usually found in its free state in normal urine, but in combination with potassium, sodium, etc. Such combinations are known as *urates*. In gout its excretion is diminished and it accumulates in the blood and tissues.

880. CREATININ, XANTHIN, ETC.—These substances represent the so-called extractives of meat, and are therefore taken into the body with the food as well as formed in the tissues by the oxidation of protein substances.

881. SALTS.—The salts eliminated in the urine are derived both from food and as products of metabolism, as described in paragraph 796. The chlorides, next to urea, constitute the chief solid component of the urine. In certain diseases, especially those associated with serous exudation, as in edema, the amount of chlorides excreted is very much diminished.

882. ABNORMAL CONSTITUENTS OF URINE.—Some of the more important abnormal substances found in urine are: albumin, glucose, acetone, indican, casts, calculi, pus, mucus, blood.

883. ALBUMIN.—As a rule, the normal renal cells do not allow albumin to pass through, but occasionally, as after extreme muscular exertion or overeating, they will. Albumin in the urine from such causes is spoken of as *temporary* or *functional albuminuria*. Albumin is frequently

of the kidneys the renal tubules become partially filled with substances which harden, thus forming *moulds* or *casts* of the tube. The casts are named either from their appearance or from the nature of the substances forming them. Thus, there are (1) *hyaline*[1] *casts*—these are pale, translucent casts formed from coagulable elements of the blood which have transuded into the tubules; (2) *pus casts*; (3) *blood casts*—these need no explanation; (4) *epithelial casts*—these are composed of cells of the walls of the renal tubes which have become disintegrated and detached. If the cells have become decomposed, they are found in the urine as masses of granules and are known as *granular casts*. If, as sometimes occurs, they become fatty, they are known as *fatty casts*. The casts, whatever their nature, are washed out of the tubes by the urine and can be found therein with the aid of a microscope.

888. Urinary Calculi or Stone.—Urinary calculi consist of deposits of solid matter that have been precipitated from the urine. They may form in any part of the urinary tract, from the tubules of the kidneys to the meatus urinarius. The most frequent causes of their formation are: (1) changes in the reaction of the urine, abnormally acid and abnormally alkaline urine tending alike to produce calculi; (2) the excretion of a smaller amount of water; (3) an increase in the less soluble constituents of the urine. Calculi vary

[1] From the Greek *hyalos*—glass.

amount of carbohydrate food. In very severe cases glucose will appear in the urine when the diet is entirely free from carbohydrates, even in starvation, because the body tissues will be oxidized and glucose can be formed from protein substances.

885. ACETONE.—Acetone is a volatile compound sometimes found in the urine of individuals suffering from diseases associated with defective metabolism, and in normal persons during continued fasting. It is thought to be the result of the incomplete oxidation of fats and, some authorities consider, of proteins.

886. INDICAN.—The putrefaction of protein material in the large intestine gives rise to a substance known as *indol*; which, after absorption, is changed, it is thought, in the liver, into indican, a less poisonous substance than the former. Traces of indican are found in normal urine, but abnormal conditions are indicated if it is present in any amount. The more common causes of an increased quantity are: (1) Excessive putrefaction of protein substances in the intestine. This is usually due either to a diseased condition of the intestine which interferes with absorption of the normal products of digestion, to constipation, or to a diet containing too much protein food. (2) Diseases of the stomach, as the result of which food lies in that organ a long time and undergoes fermentative changes.

887. CASTS.—In certain abnormal conditions

of the kidneys the renal tubules become partially filled with substances which harden, thus forming *moulds* or *casts* of the tube. The casts are named either from their appearance or from the nature of the substances forming them. Thus, there are (1) *hyaline*[1] *casts*—these are pale, translucent casts formed from coagulable elements of the blood which have transuded into the tubules; (2) *pus casts*; (3) *blood casts*—these need no explanation; (4) *epithelial casts*—these are composed of cells of the walls of the renal tubes which have become disintegrated and detached. If the cells have become decomposed, they are found in the urine as masses of granules and are known as *granular casts*. If, as sometimes occurs, they become fatty, they are known as *fatty casts*. The casts, whatever their nature, are washed out of the tubes by the urine and can be found therein with the aid of a microscope.

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[1] From the Greek *hyalos*—glass.

in size, shape, and composition; the size and shape depending largely upon their composition and location.

889. Pus.—Pus cells are often present in the urine in nephritis and other inflammatory conditions either of the kidneys or other organs of the urinary system.

890. Mucus.—Mucus may be present in normal urine in small quantities; it consists principally of the epithelial débris from the mucous surface of the urinary organs. In inflammatory conditions of these organs, especially of the bladder, mucus is poured out over their surface and appears in large quantities in the urine.

891. Blood.—Red blood-corpuscles are often found in the urine in cases of acute inflammation of any of the urinary organs, of tuberculosis, of cancer, and of renal stone or calculi. When there are many corpuscles present, the color of the urine is affected; it may even look like blood. When this is the case the condition is known as hematuria.

892. Toxicity of Urine.—Urine is a toxic substance; unless it is secreted the condition known as *uremia* will occur; but the nature of the toxin has not been definitely determined. Formerly it was thought that the urea was the poisonous principle—hence the name uremia,—but numerous experiments have shown that this is not the case. However, whatever the source of its toxicity, urine is poisonous and must not be retained within

the body. This is especially the case in illness, because the renal cells, in order to protect the body, secrete any poisonous substances that find their way into the blood, and therefore in illness the urine frequently contains a larger amount than usual of toxic material, derived in some cases from defective metabolism, in others from bacterial activity.

893. SUPPRESSION AND RETENTION OF URINE. —When the kidneys fail to secrete urine the condition is spoken of as suppression. It is usually due to disease of the kidneys. When the urine is secreted by the kidneys but retained within the bladder, the term retention is used. The causes of retention were given in paragraph 870.

CHAPTER XXI

THE SKIN AND ITS APPENDAGES

Functions of the Skin. Different Parts. Structure and Markings of the Cuticle. Cause of Blisters. Structure, Blood-vessels, Nerves, and Papillæ of the Derma. Structure of the Sudoriferous Glands. Nature, Causes, and Function of Sweat. Ceruminous Glands. Structure of Sebaceous Glands. Nature and Function of Sebaceous Secretion. The Skin as an Absorbing Organ. Inunction. The Appendages of the Skin. Structure and Growth of Hair. Cause of *Goose-Flesh*. Structure and Growth of Nails.

894. FUNCTIONS.—The skin serves: (1) as an external integument for the protection of the softer and more delicate internal tissues; (2) as an important factor in heat regulation; (3) as a sense organ; (4) as an excretory organ; (5) as an absorbing organ; (6) as a respiratory organ. In some animals, as frogs and reptiles and earthworms, the skin serves as an important respiratory organ, but in man this action is very slight, only about one-half per cent. of the total amount of oxygen taken into the body being received, and an even smaller proportion of carbon-dioxide passing off, through the skin.

895. DIFFERENT PARTS.—The skin consists of two main parts: (1) the epidermis,[1] known also as

[1] From the Greek *epi*—upon and *derma*—the skin.

from the latter by strong or long-continued irritation, and fluid collects between the two, due to the increased blood supply in the part subjected to the irritation. The separated cuticle is called a *bleb* or *blister*.

899. Structure of the Derma.—The true skin or derma consists of white fibrous and elastic connective tissue containing innumerable blood and lymphatic vessels, nerves, glands, hair-follicles, and papillæ. The upper surface is connected, as previously described, with the epidermis, and its upper surface is held to the superficial fascia lying beneath it by loose areolar tissue in which (with the exception of that in the eyelids, labia minora,[1] and scrotum[1]) there is a varying quantity of fat cells. This subcutaneous layer of tissue enables the skin to move freely on the underlying fascia.

900. Papillæ of the Derma.—The upper surface of the derma is covered with small ridges or grooves, as described in paragraph 897, and on the summit of the ridges are small papillæ, which are received into pits that are in the under surface of the epidermis. The average length of papillæ is about $\frac{1}{100}$ of an inch, and at their base the diameter is about $\frac{1}{250}$ of an inch. Some of these papillæ have loops of blood-vessels prolonged into them, and some have touch corpuscles. They are most numerous where sensation is most acute, as the cushions of the fingers, palms of the hands, and soles of the feet.

[1] Described in Chapter XXV.

stratum, the cells of which have become gradually flattened on their external surface and lost their nuclei. These are practically dead cells and are being constantly shed[1] and renewed from the cells of the deeper stratum; (2) a germinative or Malpighian layer, which consists of soft protoplasmic cells that multiply by cell-division and, pushing toward the surface, become dry, hard, and flat, and replace the cells that are being constantly brushed off. The pigment in the skin of the negro, as well as that of the nipple and elsewhere in white races, is formed in the deepest cells of the Malpighian layer. Many of the end processes of the cutaneous nerves enter the Malpighian stratum, but the epidermis has no blood-vessels.

897. Markings of the Cuticle.—The cuticle is closely adherent to the true skin and is accurately moulded over it so that the ridges and grooves which mark the surface of the latter are plainly discernible. Over most of the body these grooves are shallow and not very marked, but on the palms of the hands and soles of the feet they form definite patterns, peculiar to each individual, which never change throughout life, regardless of other changes in the hands due to change and toil. Hence the value of hand impressions in wax as a means of identification.

898. Cause of Blisters.—Though the cuticle is so blended with the derma, it is easily separated

[1] When the body temperature is high these cells are shed very quickly.

tions arising in the skin. It is for this reason that heat and cold, counter-irritants and hydrotherapeutic applications can excite so many and various reflexes.

903. GLANDS OF THE SKIN.—There are two kinds of glands in the skin: (1) sudoriferous or sweat-glands; (2) sebaceous glands.

904. SUDORIFEROUS GLANDS.—The sweat-glands are, in man, present almost everywhere in the skin, but are largest and most numerous in the axilla, the palm of the hand, sole of the foot, and forehead. Each of these glands consists of a coil of tubing lined with epithelial secretory cells and surrounded by blood-vessels and a number of nerve filaments, and has a duct through which its product is discharged upon the skin. The secretory portion of the gland, *i. e.* the coiled tube is embedded in the derma and subcutaneous tissue, and the duct opens upon the surface of the skin.

905. PERSPIRATION AND SWEAT.—These are the names given the secretion of the sudoriferous glands. The average amount of perspiration discharged in the skin during twenty-four hours is about two pints, but it may be increased to such an extent that this much or more may be thrown off in one hour. When the quantity is not much in excess of two pints in twenty-four hours it is evaporated as quickly as discharged, and is therefore called *insensible perspiration*. When the secretion is so rapid that it appears in drops

901. BLOOD-VESSELS.—The blood-vessels of the skin are found in the cutis vera only. There they form a capillary network in which the vessels are so close to each other that in many parts the point of a pin could not find space between them. From this plexus, branches pass to the skin glands and papillæ. The vessels of the skin are capable of holding from half to two-thirds of the entire blood supply of the body. Their caliber, and consequently the amount of blood they contain, is regulated largely by the vaso-motor nerves with which they are supplied.

902. CUTANEOUS NERVES.—The skin is provided with a greater variety of nerves than any other portion of the body. They have been classified as follows:

(1) The nerves concerned in the touch or pressure sense;

(2) The two sets of nerves concerned in the temperature sense which terminate in the skin in the so-called hot and cold spots;

(3) Nerves which are stimulated by pain;

(4) Vasomotor nerves; these are distributed in the walls of the blood-vessels;

(5) Motor nerves, derived principally from the sympathetic system and distributed chiefly to the glands and the arrector muscles.

As the skin contains so many sensory nerve endings from which afferent nerves pass into the spinal cord and brain, nearly every nerve-center in the body may be more or less affected by sensa-

ing the sweat glands, either by direct stimulation of the nerve endings in the glands or indirect stimulation through their cells of origin in the central nervous system. For instance, it is supposed that though increase of perspiration following a rise in the temperature of the surrounding medium is partly due to stimulation of the peripheral nerve-endings in the sweat glands, it is more largely due to reflex stimulation of the nerve-centers controlling perspiration, by impulses transmitted from such sensory nerves as are stimulated by heat. The stimulus thus originated then passes from the sweat center along motor nerves to the glands and renders them active.

908. Chemical Composition of Sweat.—The chemical composition of sweat is as follows:

Water	995	parts
Solids:	5	"
Organic acids	.9	
Salts	1.8	
Neutral fats and cholesterin	.7	
Extractives (including urea) with epithelium	1.6	
	1000	parts[1]

909. Value of the Excretory Function of the Skin.—The value of the skin as an excretory organ lies not so much in ridding the body of waste matter, as in the loss of heat from the body

[1] Kirke's *Hand-Book of Physiology*, page 511. William Wood and Co.

on the surface of the skin it is called *sensible perspiration.*

906. Conditions that Control the Secretion of Sweat.—**The secretion of sweat is decreased by** (1) cold; (2) the voiding of a large amount of urine[1]; (3) diarrhea; (4) certain drugs; (5) certain diseases, as in some cases of paralysis, diabetes, and diseases associated with fever.

The secretion of sweat is increased by (1) increased temperature of the surrounding medium; (2) a diluted condition of the blood, such as results from the copious drinking of water; (3) exercise; (4) dyspnea; (5) mental excitement or nervousness; (6) pain; (7) the class of drugs known as diaphoretics; (8) massage; (9) stimulation of the secretory nerves by electricity; (10) certain diseases, as phthisis, acute rheumatism, intermittent malarial fever.

907. Causes of Activity of Sweat Glands.—Formerly the activity of the sweat glands was supposed to be controlled by variations in the blood-flow. But that this is not always the case is demonstrated by the fact that profuse perspiration may often accompany a pallid skin, as in terror or nausea, and a decrease in the amount of perspiration is characteristic of fever, even when the skin is flushed. It is therefore supposed that the activity of the glands is regulated by stimulation of the special secretory nerve-fibers supply-

[1] The skin and kidneys seem to act reciprocally: when the secretion of one organ is increased that of the other is decreased.

from the gland passes out to the skin along the hair. At times, some of the ducts, especially those of the face, do not discharge their contents and the secretion sets to a semi-solid mass which, when the skin is squeezed, exudes like a short piece of coarse thread.

912. NATURE OF SEBACEOUS SECRETION.—The exact composition of the secretion is not known beyond that it contains fats, soaps, cholesterine, cast-off epithelium cells, albuminous matter, and inorganic salts. A sebaceous substance, similar in composition but of thicker consistency than the usual secretion of the sebaceous glands, generally coats the skin of the newly born; it is called the *vernix caseosa*.[1]

913. FUNCTION OF SEBACEOUS SECRETION.—The sebaceous secretion may be classed with the excreta, for it serves to remove waste matter from the body, but its more important purposes are to keep the skin and hair soft and pliable, and to form a thin protective layer on the surface of the skin, which prevents undue loss of heat by radiation.

914. THE SKIN AS AN ABSORBING ORGAN.—Soluble substances are very readily absorbed by the derma, but even when in solution they are very sparingly absorbed, if at all, by the unbroken cuticle. There are, however, some substances, as mercury, that when mixed with fat will be fairly

[1] From the Latin *vernix*—varnish and *caseosa*—cheesy (cheesy varnish).

by the evaporation of the water; this loss of heat being necessary to balance the production of heat that is constantly taking place. Formerly it was thought that accidents, as burns, or diseases which interfered with the excretory function of the skin, were likely to cause nephritis or even death, by failure of the skin to eliminate its share of waste matter, but investigations and experiments have shown that when such bad results are traceable to the skin they are usually due either to excessive rise of temperature due to lack of radiation and evaporation, or to irritation of the kidneys by toxic substances, or, in the case of burns, absorption from the surface of the derma of the poisonous substances due to suppuration.

910. CERUMINOUS GLANDS.—The glands contained in the skin lining the external auditory passage, called the ceruminous glands, are very similar in structure to the ordinary sudoriferous glands. The yellowish, waxy substance which they secrete is called the *cerumen*. The object of this secretion will be described in the chapter concerned with the ear.

911. SEBACEOUS GLANDS.—The sebaceous glands are found in all parts of the cutaneous surface except the palms of the hands and the soles of the feet. Each gland consists of an aggregation of small tubes overspread with minute capillaries from which a duct ascends and opens either upon the surface of the skin or, as is more common, into a hair follicle. In the latter case the secretion

ing beyond the surface of the skin is called the *shaft* or *stem;* the part embedded in the derma or subcutaneous tissue is called the *root.* This is contained in a tube-like depression which extends downward from the surface of the skin, called the *follicle.* The root ends in a minute bulbous enlargement, in the under surface of which is a cup-like depression into which a papilla derived from the follicle extends. This papilla consists of connective tissue, blood-vessels, and pigment. The external part of a hair shaft is called the cuticle. When viewed through a microscope it is seen to consist of a layer of fine scales closely overlapping each other. Beneath this is a layer of closely packed cells called the *cortical layer.* These cells and the intercellular spaces contain a varying amount of pigment, and the color of the hair depends upon the quantity. In colored hair of the scalp the cortical layer occupies the whole inside of the hair, but in white hair of the scalp, in the hair of the pubes, and in that ot the beard, there is another substance called the *medulla* or *pith.* This is composed of irregular cells and many air spaces, and in white hair there are numerous air spaces in the cortical portion as well as in the medulla.

919. Blood Supply and Growth of Hair.—Hair has no blood-vessels but receives its necessary nutrient from the blood-vessels of the papilla in the under surface of the root.

920. Growth of Hair.—The growth of hair

readily absorbed by the cuticle, especially in those parts of the body where the epidermis is thinnest (see paragraph 896). It is not known whether water is absorbed by the skin to any extent. Thirst has been relieved, when water could not be given by mouth, by immersing the individual in warm water, but some authorities consider this effect due to the hindrance of evaporation of water from the skin rather than to its absorption.

915. INUNCTION.—As stated in the preceding paragraph, substances dissolved in oil are fairly readily absorbed by the skin. The amount absorbed will be greatly increased if the material is rubbed in, and still further if the sebaceous matter covering the skin is removed, this matter being one of the causes for the non-absorptive properties of the cuticle. This is most easily removed by washing the skin with hot alcohol, ether, or benzine.

The Appendages of the Skin

916. The appendages of the skin are the hair and nails.

917. HAIR—LOCATION.—With a few exceptional areas the whole skin is studded with hair, some of which is exceedingly fine and extends but little beyond the hair follicle; but some, as that of the scalp, is long and coarse.

918. NAMES AND NATURE OF THE VARIOUS PARTS OF A HAIR.—The portion of a hair project-

cuticle of the skin and hair, by a peculiar growth and modification of the underlying cells. Each nail is convex on its outer surface and concave on its inner side. It is adherent to, and accurately moulded upon, the underlying derma, just as the epidermis is in other parts of the body. The part of the cutis beneath the nail is termed the *matrix*,[1] because it is the part from which the nail is derived. The lower edge of the nail, which is held in a shallow crescentic fold of the matrix, is termed the root; the exposed portion is known as the body, and the part projecting beyond the finger as the free edge. The tissue of the matrix, except near the root of the nail, is highly vascular. Near the root it is more opaque and less vascular; hence the nail, the substance of which is somewhat transparent, has a pinkish hue, except immediately above the root, where it is white. The white portion, on account of its cresentic shape, is called the *lunula*.

923. Growth.—The growth of the nail is accomplished by the continual dividing of the cells of the matrix at the root and under surface of the nail, and if a nail is lost through accident or disease a new one will form, provided the surface of the matrix has not been too badly injured.

[1] Latin *matrix*, from *mater*—a mother.

takes place by multiplication of the soft cells in the root which, becoming elongated and pushing upwards, go to form the cortical layer of the hair. The cuticle is derived from the corticle, the cells becoming harder and changing their shape as they are pushed to the surface. A scalp which is favorable to the growth of hair is thick and pliable and moves freely over the bones of the skull. If the scalp is thin and drawn tightly over the skull it will tend to constrict the blood-vessels, lessen the supply of blood to the scalp,and cause atrophy of the roots of the hair by pressure. In such cases massage of the head, by loosening the scalp and improving the circulation of blood in it, may be of great benefit.

921. CAUSE OF GOOSE-FLESH.—The rough appearance that the skin often assumes as the result of cold or fright is known as *goose-flesh*. It is due to the action of small muscles termed the *arrector* or the *erector muscles*. These are attached to the base of the follicles on the side toward which the hairs lie. The follicles naturally slant obliquely, but when the arrector muscles contract they are pulled upward; this gives the skin a rough appearance and makes the hair stand somewhat erect.

The Nails

922. NATURE.—The nails consist of flattened, horny cells produced, like the outer layer of the

where it is interpreted. We, therefore, both see and hear with our brains. If a person cuts his finger he feels the pain in his brain, but he unconsciously projects the sensation to the part that he knows to be injured. Many individuals who have had a limb amputated, if they have pain in the stump, will complain of pain in the amputated part because they continue to project sensation to the part to which they have been accustomed to project it.

927. CLASSIFICATIONS OF SENSATIONS.—Sensations have been classed as common and special sensations, or, the more modern terms, internal and external sensations. **Common or internal sensations** embrace those which we project to the interior of the body. They were called *common* because it is very difficult to distinctly localize some of the sensations of this class. Examples of internal sensations are: pain, hunger, thirst, muscle-sense, fatigue, sexual sense, sensations arising in the viscera, as the desire for defecation or urination.

928. **External sensations** include all those which we project to the exterior of the body. They were named *special* senses because it is easy to locate the special organ in which the nerve impulse that gave rise to the sensation was started. This class includes: touch, which comprises pressure and temperature sense; taste, smell, sight, hearing. A few sensations may be either internal or external, *e. g.*, in temperature sense,

CHAPTER XXII

SENSATIONS

Origin of Sensation. Essentials of a Sense Organ. Where Sensations are Perceived. Classification of Sensations. Nature of the Sensations of Pain, Hunger, Thirst, Muscular Sense, Fatigue, Pressure Sense, Temperature Sense, Smell, and Taste.

924. ORIGIN OF SENSATION.—Every sensation arises from the stimulation of a special form of nervous mechanism known as a *sense organ*.

925. NATURE OF SENSE ORGANS.—The essential parts of a sense organ are: (1) a peripheral organ for the reception of the stimulus; (2) a nerve for conducting it; (3) a nerve center in the brain for the perception and interpretation of the stimulus.

926. WHERE SENSATIONS ARE PERCEIVED.—In all cases sensations are felt and interpreted in the brain. This fact is not generally appreciated, for we are accustomed to projecting our sensations from the brain to the part stimulated. We say that we see with our eyes and hear with our ears; in reality we do no such thing. The eye and the ear contain the nerve-endings which receive the stimuli, and they pass the impulse to the brain

evoke appetite and also stimulate the secretion of the digestive juices.

932. THIRST.—This sensation is projected to the pharynx, though, when the water content of the body is low, it is probably evoked by stimulation of certain sensory nerves in many of the organs. Ordinarily, however, it is due to the stimulation of special sensory nerves in the pharynx caused by drying of its mucous membrane.

933. FATIGUE.—See Chapters VI and VII.

934. MUSCULAR SENSE.—To the so-called muscular sense is due our knowledge of the condition and position of our muscles, and of the joints and limbs moved by them. This knowledge enables us to control our movements and to maintain our balance when in the erect position. Muscle-sense arising in those muscles of the eyeballs concerned with focusing, together with the sense of vision, helps us in forming our judgments of distance and of the size of objects. It is to muscle-sense also that our idea of the degree of resistance offered us by objects is due, and, in connection with the sense of pressure, our idea of their weight. This sense is due to stimulation of special sensory nerves distributed in the muscles.

935. PRESSURE OR TACTILE SENSE.—The nerves connected with the pressure sense are widely distributed through the skin and certain mucous membranes. These nerves end either in the hair follicles or, in locations where there are no hairs, in the so-called touch or tactile corpuscles

when we touch a cold or hot object we project the sensation to the exterior; but if the sensation of heat or cold is due, for instance, to the weather we project the sensation to the interior; we say, "I am hot," or "cold." Pain is another example of a sensation that may be projected to either the exterior or interior of the body.

929. PAIN.—Formerly, it was thought that the sense of pain might be due to over-stimulation of other sensory nerves as, for instance, the nerves connected with the senses of pressure and temperature, but it is now considered that there are special sense organs for this sensation.

930. HUNGER.—There have been many theories advanced to account for this sensation. The present belief is that hunger is due to strong contractions of the stomach which occur at fairly regular intervals. Under some conditions, as in severe illness and fatigue these periodic contractions may not occur or they may be weaker than usual. This is thought to account in part for the lack of hunger usual in such conditions. The contractions causing hunger favor digestion if food is taken at the time.

931. APPETITE.—Formerly, this sensation was thought to be a preliminary or slight stage of hunger, but it is now considered that the two sensations are fundamentally different, appetite being of psychic origin and connected with experiences of taste and smell. Thus, the thought, as well as the taste, of some especially liked food will

evoke appetite and also stimulate the secretion of the digestive juices.

932. THIRST.—This sensation is projected to the pharynx, though, when the water content of the body is low, it is probably evoked by stimulation of certain sensory nerves in many of the organs. Ordinarily, however, it is due to the stimulation of special sensory nerves in the pharynx caused by drying of its mucous membrane.

933. FATIGUE.—See Chapters VI and VII.

934. MUSCULAR SENSE.—To the so-called muscular sense is due our knowledge of the condition and position of our muscles, and of the joints and limbs moved by them. This knowledge enables us to control our movements and to maintain our balance when in the erect position. Muscle-sense arising in those muscles of the eyeballs concerned with focusing, together with the sense of vision, helps us in forming our judgments of distance and of the size of objects. It is to muscle-sense also that our idea of the degree of resistance offered us by objects is due, and, in connection with the sense of pressure, our idea of their weight. This sense is due to stimulation of special sensory nerves distributed in the muscles.

935. PRESSURE OR TACTILE SENSE.—The nerves connected with the pressure sense are widely distributed through the skin and certain mucous membranes. These nerves end either in the hair follicles or, in locations where there are no hairs, in the so-called touch or tactile corpuscles

referred to in Chapter XXI. The nerves ending in the hair follicles are stimulated by pressure upon the hairs. Pressure nerves are not distributed evenly, but are much more abundant in some parts of the skin than in others, as can be seen by the following table, which gives the distance between the points at which experiments have shown pressure can be felt:

Tip of tongue	*1 mm.*
Tip of finger (front)	*2 mm.*
Middle of palm	*8–9 mm.*
Lip	*9 mm.*
Forehead	*22 mm.*
Back of hand	*31 mm.*
Back of neck	*60–70 mm.*[1]

The pressure sense can be rendered much more acute by practice, as is demonstrated in the blind.

936. THE TEMPERATURE SENSE.—Certain nerve-endings are stimulated by cold and others by heat, and the points on the epidermis over these endings are called respectively the *cold* and *hot spots.*[2] These endings can be stimulated also by

[1] *The Nervous System*, page 119. By James Dunlop Lickley, M.D. Longmans, Green & Co.

[2] The existence of these spots may be ascertained by moving a metallic point gently over the skin. If the point has a temperature below that of the skin it will be noticed that at certain points it arouses a feeling of contact or pressure and in others one of cold. If, on the other hand, the instrument has a higher temperature than the skin, the sensation aroused will be either pressure or heat.

CHAPTER XXIII

THE EYE AND THE SENSE OF VISION

Names of the Main Divisions of the Organ of Vision. Names, Location, Structure, and Function of the Appendages of the Eye. Structure of the Orbit. Size, Shape, and Divisions of the Eyeball. Structure and Function of the Different Parts of the Eyeball. Location and Function of the Optic Nerve. Nature of Accommodation of the Refractory Apparatus of the Eyeball. Common Defects of Accommodation. Physiology of Vision. Judgments of Size, Motion, and Solidity of Objects. Origin of Color. Color Vision. Color Blindness.

939. THE ORGAN OF VISION AND APPENDAGES.—The organ of vision may be said to consist of the eyeballs, the optic nerves, and the optic nerve-centers in the brain. In addition to these principal parts there are also various appendages which are necessary for the protection and functioning of the eyeball; these are: the eyebrows, eyelids, eyelashes, the lachrymal apparatus, the conjunctiva, and for each eye four recti—straight—and two oblique muscles.

940. THE EYEBROWS.—The eyebrows are two thickened ridges of skin covered with short hairs. They are situated on the upper border of the orbits and serve to protect the eyes from too vivid light, dirt, and perspiration.

senses are often confused and what we designate as the taste of some foods, especially those that owe their flavor to volatile substances, is very often largely their odor, the substances to which the odor is due being liberated during mastication and ascending through the pharynx. This accounts for the loss of *taste* that so frequently complicates a cold in the head or any other condition causing a loss of smell.

The senses of sight and hearing will be discussed in the two following chapters.

sists of a secreting portion—the lachrymal gland and conjunctiva—and a conducting portion—the lachrymal canals, lachrymal sac, and nasal duct. The gland is situated just within the orbit, at the upper and outer side. It is about the size of a small almond and its structure is very similar to that of

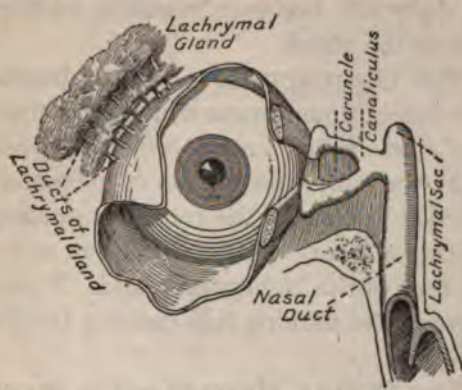

FIG. 123.—The lachrymal apparatus of the right eye.

the salivary glands. At the inner end of each upper and lower lid is a small opening—*the puncta lachrymale—the lachrymal point*—from which a small canal leads to the lachrymal sac. The lachrymal sac is the upper enlarged end of the nasal duct; the latter is a short canal—about three-quarters of an inch in length—which opens into the nose. The function of the lachrymal gland is the secretion of tears. These are necessary to keep the anterior surface of the eyeball moist and free from dirt. They reach their destination by means of numerous

941. THE EYELIDS.—These are two movable curtains which when closed cover the eyeball. The upper lid is larger and moves more freely than the lower lid. The main substance of the lids consists of a dense fibrous tissue known as the *tarsal cartilage* and the small muscles which are concerned in the movements of the lids. The outer surface of each lid is covered with a thin skin and its inner surface is lined with a delicate membrane —the conjunctiva. The free edges of the lids are covered with a line of short hairs—the eyelashes—which help to protect the eyes from too strong light and dirt. Embedded in the substance of the lids is a row of small glands called the meibomian glands, the ducts of which open on the under surface of the lids, just above the eyelashes. These glands secrete an oily fluid which tends to keep the tears from flowing over onto the face and prevents adhesion of the lids. The opening between the free margin of the lids is called the *palpebral*[1] *fissure*. It is the width of this space that gives to the eyes the appearance of largeness and smallness. There is very little difference in the size of the eye in different individuals of the same age. The angle at the outer end of the fissure is called the outer *canthus*, and that on the nasal side the inner *canthus*.[2]

942. THE LACHRYMAL[3] APPARATUS.—This con-

[1] From the Latin *palpebra*—the eyelid.
[2] From the Greek *kanthos*—the angle of the eye.
[3] From the Latin *lachryma*—a tear.

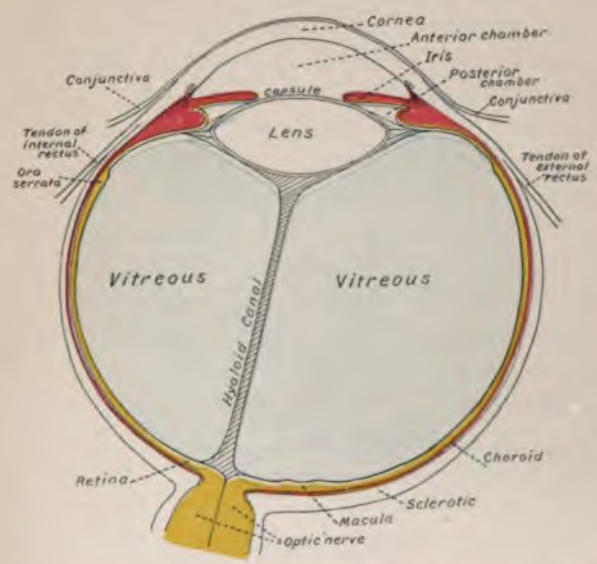

FIG. 124.—Diagram of the right eye in horizontal section, showing the upper surface of the lower segment.

small ducts which open from the secreting portion of the gland and are spread over the front surface of the eyeball by the movements of the lids. Ordinarily all excess secretion flows through the lachrymal puncta, canals, sac, and nasal duct into the nose. Excessive secretion or obstruction in the canals or duct will, however, result in an overflow of tears over the cheek.

943. THE CONJUNCTIVA.[1]—The conjunctiva is a delicate mucous membrane which lines the inner surface of the eyelids and is reflected over the front of the eyeball. The portion of the membrane of the eyeball known as the cornea is exceedingly thin and transparent. The conjunctiva secretes a fluid like that of the lachrymal gland. This secretion prevents the moving lids causing friction on the eyeball.

944. THE OCULAR MUSCLES.—The muscles of the eye are, in description, divided into two groups: (1) the intrinsic[2] muscles, which include the *ciliary muscle* and the *muscles of the iris* (these will be described later), and (2) the extrinsic[3] muscles, which include the four recti or straight and the two oblique muscles. As stated in Chapter VI, these muscles have their origin at the back of the orbit and are inserted in the outer tunic or coat of the eyeball. They serve to move the eyeball. Normally the extrinsic muscles of the two eyes work in unison; thus, to view an object near

[1] From the Latin *con*—together and *junctum*—to join.
[2] Internal. [3] External.

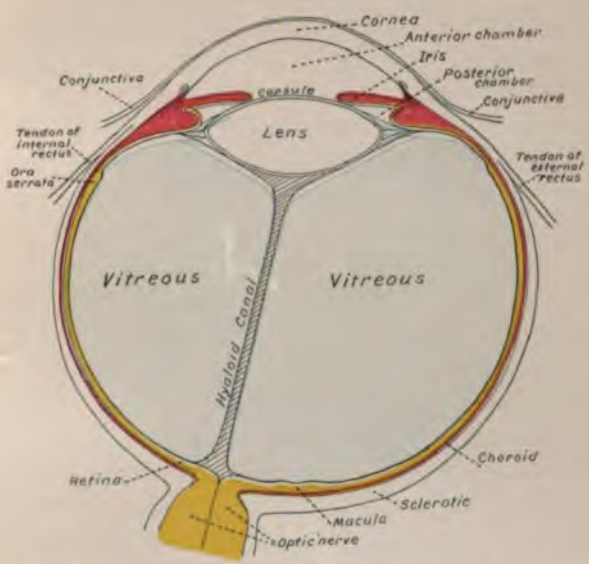

FIG. 124.—Diagram of the right eye in horizontal section, showing the upper surface of the lower segment.

and in front of the eyes both eyes will converge; to view an object at the right both eyes will turn toward the right, etc. This concord in movement is necessary in order that the image of the object may fall upon corresponding spots of the retina of each eye. If it fail to do so double vision will result, *i. e.*, the individual will see two objects where there is only one. This happens sometimes as the result of weakness or paralysis of some of the muscles in alcoholic and some other forms of poisoning and in certain diseases of the eye.

945. The Orbit.—The orbits are the two bony cavities in which the eyeballs are contained. Each orbit is formed by the union of seven of the bones of the skull, viz.: the sphenoid, ethmoid, frontal, lachrymal, malar, superior maxillary, and palate. The orbits are funnel-shaped, the large end being directed forward and the small end backward. The latter terminates in an opening known as the optic foramen, through which the optic nerve and the ophthalmic artery pass from the brain to the eye. There is another opening in the posterior part of each orbit which provides a passage for the ophthalmic vein and the nerves, the purpose of which is to carry impulses to and from the muscles. The optic nerve is concerned with vision only. The orbits are lined with fibrous tissue and contain a pad of fat at the back which supports the eyeball. In diseases which cause emaciation this fat is absorbed, and the eyes sink deeper into the orbits. The outer surface of the connective tissue

and fat is covered with one side of a thin serous sac, the other side of which is attached by means of delicate strands of areolar tissue to the posterior surface of the eyeball. This sac, which is called the *capsule of Tenon*, like all serous membranes secretes a lubricating fluid, and this prevents friction as the eyeball moves in the orbit.

946. SIZE, SHAPE, AND DIVISIONS OF THE EYEBALL.—The human eyeball is a hollow, somewhat spherical body. It is made up of the segments of two spheres, one placed in front of the other. The posterior sphere, which is the larger of the two, constitutes about five sixths of the eyeball; and the anterior, which fits into the posterior sphere much as a watch-crystal fits into its case, forms the other one sixth. In the interior, the two spheres are divided by a transparent, fibrous substance called the *lens*. This will be described later.

947. COATS OF THE WALL OF THE EYEBALL.—The wall of the eyeball consists of three coats or tunics. The tissue forming the two outer ones differs in the posterior and anterior spheres, and the parts are therefore known by different names, but they are directly continuous with each other. The names of the coats are: (1) the sclera and cornea, (2)[1] the choroid, ciliary zone, and iris; (3) the retina.

[1] The second or middle coat of the eyeball is known also, on account of the abundant blood supply, as the vascular coat, and, on account of its dark color, as the uveal tract, the word uveal being derived from the Latin *uva*—grape.

948. **The sclera**[1] or **sclerotic coat,** often called *white of the eye*, is a strong, opaque, fibrous membrane. It is the strongest coat and the one upon which the maintenance of the shape of the eyeball depends. The sclera varies in thickness from one half of a millimeter to one sixth of a millimeter. It is thinner in children than in adults, which is why the *white* of children's eyes is so much clearer and bluer than that of adults, the blue color being due to the showing through of the darker coat underneath.

949. **The cornea,** which is continuous with the sclera, consists of layers of exceedingly thin transparent connective tissue held to each other by fine fibers. It contains numerous lymph-spaces and nerves, but no blood-vessels; it is therefore dependent on the lymph contained in the lymph-spaces for its supply of nutrient and thus on the blood supply of the surrounding tissues, from which the lymph is derived.

950. **The choroid**[2] **coat,** which is attached to the under surface of the sclera, consists almost entirely of an interlacement of small blood-vessels, held together with a delicate connective tissue in which are many pigment cells. The numerous blood-vessels and pigment cells of the choroid make the membrane so dark and opaque that it serves to darken the chamber of the eye, which, like the dark chamber of the photo-

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grapher's camera, prevents the reflection of light.

951. **The ciliary[1] zone** differs from the choroid in containing considerable muscular tissue called the *ciliary muscle*, and, on its under surface, a series of fine ridges called the *ciliary processes*.

952. **The iris,[2]** which is continuous with the ciliary zone, is the colored membrane that hangs like a round screen behind the transparent cornea. It consists of exceedingly delicate connective and muscular tissue with numerous small blood-vessels, nerve fibers, and a varying amount of pigment cells. The color of the iris depends upon the amount of pigment cells. When they are abundant the iris will be either black, brown, or gray; when they are scanty the iris will be blue, because the blue shade of the retinal cells will show through the membrane of the iris.

953. **The pupil** is the aperture in the center of the iris through which the light enters the eye.

954. **The retina[3]** is the inner and nervous tunic of the eye. It results from the spreading out or expansion of the optic nerve, and extends from the optic nerve entrance forward to the margin of the pupil. At the posterior border of the ciliary processes it loses the nervous element, characteristic of the portion lining the choroid, and consists

[1] From the Latin *cilia*—eyelashes. The word is used in anatomy for hair-like processes.

[2] From the Latin *iris*—a rainbow.

[3] From the Latin *rete*—a net.

chiefly of a thin layer of connective tissue and pigment cells. The part of the retina underneath the choroid has a very complicated structure. It consists principally of several layers of specialized nerve tissue held together with delicate connective tissue. The only layers that need be mentioned here are those more particularly affected by light, viz.: the pigment layer which lies next the choroid coat, and the nervous layer inside of this, called, from the shape of its parts, the rods and cones. It is this layer which is sensitive to light and receives the image of external objects. It may be likened to the sensitized plate of a camera.

955. The Yellow Spot, Fovea Centralis, and Blind Spot.—Near the center of the retina is a yellow spot called the *macula lutea*,[1] in the center of which is a depression known as the *fovea centralis*.[2] This is the part of the retina that is most sensitive to light. The optic nerve enters the eye a little to the nasal side of the yellow spot. There are no rods and cones at this point and it is therefore insensible to light and is called the *blind spot*. To prove the presence of the blind spot, close the left eye and gaze steadily at the cross below with the right eye; move the book

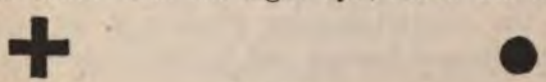

Fig. 127.

[1] From the Latin *macula*—spot and *lutea*—yellow.
[2] From the Latin *fovea*—depression and *centralis*—central.

slowly to and from the eye. In one position the circular spot will apparently disappear.

956. THE OPTIC NERVE.—The optic nerve from each eye passes backward through an opening—the optic foramen—near the apex of the orbit. The two nerves come together a short distance back of the orbits and form what is known as the optic chiasma, and fibers coming from the inner or nasal side of each retina cross to the optic nerve, or, as it is called, the optic tract, of the opposite side. The fibers from the outer side of the retina are continued on in the optic tract of the same side. The nerves end finally in the cortex of the occipital lobe.

957. THE HUMORS OF THE EYE.—The posterior sphere or chamber of the eye is filled with a transparent, jelly-like substance termed the *vitreous*[1] *humor*, and the anterior chamber contains a clear, watery fluid known as the *aqueous*[2] *humor*.

958. THE CRYSTALLINE LENS.[3]—Between the aqueous humor and the vitreous is a transparent biconvex—*i. e.*, convex on both its anterior and posterior surfaces—fibrous substance called, from its exceeding transparency, the *crystalline lens*. This is enclosed in a thin, transparent membrane termed the *capsule*. The lens is supported in place by the counterbalancing pressure of the aqueous and vitreous humors and by the *suspensory liga-*

[1] From the Latin *vitrum*—glass and *humor*—fluid.

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[3] A description of lenses will be found in the Glossary.

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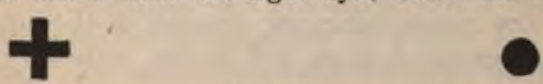

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ment, a strong, elastic membrane which is fused to the anterior surface of the capsule and, at either side, to the ciliary processes between the choroid and the iris.

959. Function of the Crystalline Lens, Humors, etc.—The cornea, the crystalline lens, the aqueous and vitreous humors, the ciliary muscle, and the suspensory ligament constitute what is known as the refractive apparatus. This is so called because it is to the cornea, lens, and humors that the refraction of the rays of light entering the eye is due. By this is meant that as the rays of light pass through these media they are bent and so converge, as they will when passing through any convex lens, and they are thus brought to a focus on the retina. When, for any reason, rays of light are not focused properly on the retina, the vision of objects is blurred and indistinct. The part that the ciliary muscle and suspensory ligament take in refraction[1] will be described in paragraph 962.

960. Why Opaque Objects are Visible.—Rays of light which strike the surface of an opaque object are partly absorbed and partly reflected. It is through the agency of the reflected light that objects are visible—*i. e.*, we see an object because light from that object enters the eye.

961. Accommodation for Far and Near Objects.—In order that divergent rays of light com-

[1] For further description of the nature of refraction and light, see Glossary.

ing from an object nearer than twenty feet may be focused on the retina and not behind it, it is necessary that the lens should become more convex than it is when the eye is at rest or when looking at distant objects, and the nearer the object the greater must be the degree of convexity. This increase in the convexity of the lens and, consequently, its refractive power, is spoken of as accommodation.

962. MECHANISM OF ACCOMMODATION.—The ciliary muscle is thought to be the active agent in accommodation, but its exact influence on the refractory apparatus is as yet imperfectly understood. The more generally accepted theory is that when the eye is at rest or fixed upon distant objects the suspensory ligament exerts a tension upon the lens which keeps it flattened, particularly along the anterior surface to which it is attached, but when the eye becomes fixed on near objects—especially in such acts as reading and in doing fine work—the ciliary muscle contracts and in doing so draws forward the choroid coat and thus relaxes the tension of the suspensory ligament, in consequence of which the anterior surface of the lens becomes more convex.

963. SOME OF THE MORE COMMON CONDITIONS THAT AFFECT ACCOMMODATION.—As age advances the lens becomes harder and the suspensory ligament and capsule less elastic, in consequence of which the shape of the lens is less easily adjusted and it therefore becomes difficult to see small

mitted to the brain result in sight. In the rods a peculiar kind of red pigment, termed visual purple, has been found, and it is thought that this and the pigment of the retina layer next the choroid play an important part in these changes.

969. Inversion of Images.—Owing to the nature of the refraction or bending of the light rays as they enter the eye, which causes them to cross each other as shown in Fig. 139,[1] the figure of objects is inverted on the retina. That we see them erect is because "experience has taught us to project the visual sensation arising from the stimulation of any given point on the retina to that part of the external world from which the stimulus arises—that is, to the luminous point giving origin to the light rays."[2]

970. Estimation of the Size of Objects.—The apparent size of objects depends upon their nearness, and if the eye were a mere machine a man at the distance of ten feet would be taken to be ten times as large as one at one hundred feet. But the eye being backed by the reason, by experience, and by muscular sense arising from the degree of accommodation necessary to focus the eye, it is possible to form a correct estimate of the comparative size of the two figures.

971. Estimation of Movement.—We judge of the movement of an object partly from the

[1] See Glossary.

[2] *Text-Book of Physiology*, page 303. Howell. W. B. Saunders Co.

motion of its image over the surface of the retina, and partly from the motion of our eyes following it.

972. ESTIMATION OF SOLIDITY OF OBJECTS.—The images of objects are portrayed on the retina as flat figures and our judgment of their solidity is due chiefly to the following conditions: (1) In binocular vision the images of the two retinæ are not exactly alike, the retina of the right eye getting more of the right side of the object, and the retina of the left eye more of the left side, and the fusion of the two different aspects is the principal factor in giving rise to judgments of solidity; (2) the effect of light and shade; (3) knowledge gained through pressure and muscle sense.

973. SUMMARY.—The parts of the eye more particularly concerned in vision are: (1) the dark chamber formed by the dark colored choroid and iris; (2) the iris which answers to the diaphragm of the photographer's camera and regulates the amount of light admitted to the chamber through the pupil; (3) the transparent surfaces—the cornea and lens—and humors by means of which the rays of light emitted by external objects are brought to a focus on the retina—these take the place of the lens of the camera; (4) the accommodation apparatus—the ciliary muscle and ligament—which regulates the convexity of the cornea, lens, and humors, and thereby the degree of refraction in the rays of light entering the eye—this answers

to the focusing arrangements of the camera; (5) the retina upon which the rays of light emitted by external objects are brought to a focus and the inverted images of the objects imprinted, just as a picture is formed on the sensitized plate of the camera; (6) the optic nerve which carries the impulses caused by the stimulation of the rods and cones of the retina of the brain. Also, there may be mentioned the recti and oblique muscle by means of which the coördinate movements of the eyeballs are attained.

Color Vision

974. NATURE OF COLOR.—It is the accepted belief (1) that all space is filled with a medium named ether that is so transparent and subtle that it cannot be perceived by any of our senses; (2) that light is the result of transverse vibrations or waves of this ether, and (3) that the color of light is dependent upon the length of the waves; by *length of the waves* being meant the distance between waves, *e. g.*, when there are about 34,000 waves to the inch they produce the sensation of red light; when they are still shorter—*i. e.*, closer together—they produce the sensation of orange color; when still shorter, yellow, then green, blue, indigo, and when they have become so short that there are about 60,000 to the inch, violet. Between these decided colors there are a great many tones, produced by difference in the length of ether waves.

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stance and of the changes caused in it, but nothing has been proved.[1]

977. Color Blindness.—Some people cannot distinguish certain colors, especially red or green. This inability is known as color blindness. One explanation of the condition is about as follows: It is thought that different parts of the retina respond to different color sensations and that in individuals who are unable to perceive a certain color the cones in the part of the retina that should respond to that color have not been properly developed. Another explanation is that the chemical substance concerned in color vision is deficient in the parts that should respond to the red or green, as the case may be, color wave.

[1] A description of some of the theories will be found in *Text-Book of Physiology*, page 352. Howell. *Scientific Ideas of To-day*, page 204. Charles R. Gibson. J. B. Lippincott Co. *Hand-Book of Physiology*, page 752. Kirk.

White is simply a totality of effect produced by the simultaneous effects of many colors falling upon the retina.

975. THE COLOR OF BODIES.—The color of light must be distinguished from the color of a body. The color of light, as we have seen, depends upon the length of its wave, but the color of a body depends upon the light it reflects, or, if it is transparent, upon the light which passes through it; *e. g.*, an opaque body that gives rise to a sensation of red does so because it reflects red light and absorbs the light of other colors incident upon it. An object appears black when it neither reflects nor emits light. Some artificial lights do not contain all the variety of wave lengths contained in sunlight—daylight—and objects that would reflect these colors, if present, fail to do so. This is why the color of some things is different by daylight than by artificial light.

976. THEORIES OF COLOR VISION.—In order that color can be perceived by the brain it is necessary that the retina be stimulated in some special manner by the color rays entering the eye. How it is so stimulated is not known. It is thought, however, that there is in the retina some compound chemical substance which is acted upon by the incoming color waves so that chemical changes are brought about which produce the nerve impulses that give rise to those color sensations which we experience. There are many theories regarding the nature of the chemical sub-

part is hollowed out of the temporal bone. In adults the canal is about 1¼ inches long. Its direction is forward and inward and it is slightly curved, so that its central portion is the highest. For this reason, in order to see the drum, or when giving irrigations, it is necessary to raise the outer cartilaginous portion of the canal by pulling the auricle upward and backward. In small children, owing to lack of development of its bony portion, the shape of the canal is different and it is best straightened by drawing the auricle downward and backward. The canal is covered with skin that contains a number of small glands called the *ceruminous glands*, which secrete a sticky substance known as *cerumen* or *ear wax*. Near the external meatus or opening are several stiff hairs. These and the cerumen serve to protect the ear from the entrance of foreign substances. The inner end of the canal is shut off

FIG. 128.—Vertical section through the external auditory meatus and tympanum, passing in front of the fenestra ovalis.

CHAPTER XXIV

THE EAR AND THE SENSE OF HEARING

Main Divisions of the Ear. Structure, Anatomy, and Function of the External, Middle, and Inner Ear. Divisions of the Auditory Nerve. Physiology of Hearing. Function and Mechanism of the Semicircular Canals.

The Ear

978. MAIN DIVISIONS.—The ear consists of three main parts termed the external, middle, and internal ear.

979. THE EXTERNAL EAR.—This consists of the auricle[1] or pinna[2] and the auditory canal.

980. **The auricle,** except the lower portion or lobe, consists of a cartilaginous framework containing a small amount of fatty tissue and a few small muscles. In the lobe, the cartilage is replaced by connective tissue. The whole auricle is covered with skin.

981. **The exterior portion of the wall of the auditory canal** is cartilaginous—the cartilage being continuous with that of the pinna. The posterior

[1] From the Latin *auris*—the ear. *Auricula*—the external ear.
[2] From the Latin *pinna*—a wing.

the center, or else some of this rarefied air escapes through the Eustachian tube and causes a partial vacuum within the cavity, which creates a suction that pulls down the central portion of the membrane and also causes congestion of the mucous membrane lining the cavity. Unless the obstruction is relieved and the pressure on either side the drum equalized, the conditions just described will become permanent and dullness of hearing follow.

FIG. 129.—Chain of small bones and their ligaments, seen from the front in a vertical, transverse section of the tympanum.

983. THE BONES OF THE MIDDLE EAR. —Stretching across the cavity of the middle ear, from the tympanic membrane to the oval window, is a chain of three small bones called from their shape: the *malleus*—hammer; *incus*—anvil; and *stapes*—stirrup. These ossicles are held in position and attached to each other and to the drum membrane and the membrane of the oval window by minute ligaments and muscles. The handle of the hammer is attached to the drum membrane; the base of the anvil is connected with the head of the hammer; one side of the stirrup is held to

from the inner ear by a membrane known as the *tympanic* or *drum membrane* which is stretched across the opening between the two cavities.

982. THE MIDDLE EAR OR TYMPANUM.[1]—The middle ear is an irregular bony cavity situated in the temporal bone of the skull. It measures about half an inch in height and in width, and five-eighths of an inch in length. Its upper wall, which separates it from the brain, is exceedingly thin—about one twenty-fourth of an inch in thickness. In the inner wall of the tympanum—opposite the drum membrane—are two openings communicating with the inner ear, both of which are covered with a fibrous membrane. One is called the *fenestra rotunda* or *round window* and the other the *fenestra ovalis* or *oval window*. In the posterior wall is an opening into the mastoid antrum, and through this opening inflammation often extends from the middle ear into the mastoid cells, causing a very serious condition known as *mastoiditis*. In the anterior wall also there is an opening into a small tube—the Eustachian tube—which extends into the throat. The function of this tube is to ventilate the middle ear and to equalize the air pressure on both sides of the drum membrane between the external and middle ear. If the tube becomes blocked, as it often does in inflammatory conditions of the nose and throat, the air in the inner ear becomes heated and consequently expands and either pushes up the tympanic membrane in

[1] From the Greek *tympanon*—a drum.

ductus endolymphaticus. On the inner wall of these sacs are numerous hair-like cells projecting into the endolymph, round which terminal filaments of the vestibular branch of the auditory nerve are twined. Lying among the hair cells are numerous minute crystals of carbonate of lime called otoliths.[1]

986. The **cochlea**[2] opens from the saccule or front end of the vestibule. It is a spiral tube shaped like a snail shell, coiled two and one half

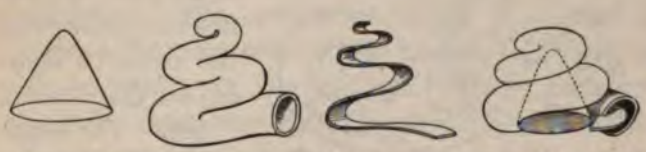

FIG. 130.—Constituent parts of the osseus cochlea—the modiolus, the coiled tube, the spiral lamina—isolated in the first three pictures, and combined in the fourth. Diagrammatic.

times round a small pillar called the *modiolus*,[3] from which a thin *spiral lamina*[4] of bone projects that helps to divide the interior of the canal into two passages or *scala*.[5] There are numerous openings in the modiolus and lamina for the passage of nerve fibers which arise from ganglia of nerve cells contained within the modiolus. From

[1] From the Greek *ous*—the ear and *lithos*—stone (the ear stones).

[2] From the Latin *cochlea*—a snail shell.

[3] From the Latin *modiolus*—the nave of a wheel.

[4] From the Latin *lamina*—a thin plate or scale.

[5] From the Latin *scala*—a staircase.

the long process of the anvil, and its foot-piece is attached to the fibrous membrane stretched across the oval window.

984. THE INNER EAR OR LABYRINTH.—The inner ear is contained in a very intricate series of cavities hollowed out of the temporal bone called the bony labyrinth. Within the bony labyrinth is a membranous sac of somewhat similar shape, known as the *membranous labyrinth.* It is held to the bone in places by bands of fibrous tissue. The space between the bone and membrane is filled with a watery fluid called *perilymph,*[1] and the cavities within the membrane are filled with a similar fluid called *endolymph.*[2] The inner ear is divided into three distinct, though connected, parts known as the *vestibule,* the *cochlea,* and the *semicircular canals.*

985. The **vestibule** is the central cavity of the labyrinth; it communicates with the cochlea in front, with the semicircular canals behind, and in its outer wall is the oval window which communicates with the middle ear, and to which, within the latter, the foot of the stapes is connected. The membrane within the vestibule is somewhat constricted in the center so that it appears like two small sacs connected with a Y-shaped tube; the two sacs are called respectively the saccule[3] and the utricle,[4] and the connecting tube is called the

[1] From the Greek *peri*—around and *lympha*—clear water.
[2] From the Greek *endo*—within.
[3] From the Latin *sacculus*—a little sac.
[4] From the Latin *utricle*—a small skin.

covered with hair-like cells similar to those of the utricle and saccule, to which are distributed nerve-endings of the vestibular branch of the auditory nerve. As will be seen later, the semicircular canals, and probably the vestibule, are not concerned in the sense of hearing.

988. The Auditory Nerve.—The auditory nerve trunk contains two distinct sets of nerve fibers, the origin, destination, and function of which are entirely different. One set of fibers is known as the *cochlear branch* and the other as the *vestibular*. The cells from which the principal fibers of the cochlear branch arise are situated in the modiolus of the cochlea. These cells are bipolar,[1] and one axon from each cell passes through the walls of the modiolus and the lamina and is distributed around the hair-like cells of the cochlea. The other axon passes through an opening in the internal ear—the *internal auditory meatus*—which leads to the brain and passes to what is known as the *cochlear root of the auditory nerve* at the lower edge of the pons Varolii.[2] Thence fibers pass to the center of hearing in the cortex of the temporal lobe of the cerebrum.

989. The peripheral termination of the vestibu-

[1] Described in paragraphs 309–311.

[2] Nerve fibers leaving the ear do not pass to their destination in the pons or from the pons to the cerebrum as continuous strands, but there are as it were several relay stations of gray matter in which the fibers end and transmit their impulses to fibers arising from the cell bodies constituting this gray matter. See paragraphs 335–342.

the lamina, a thin membrane extends to the outer wall of the cochlea. The lower part of this, called the basilar membrane, consists of fine fibers which, though held together, are sufficiently independent to be considered as strings. It forms the foundation for a structure consisting of thousands of hairlike cells supported by minute rods. These constitute what is known as the organ of *Corti*.[1] It is to these hair cells that the principal part of the nerve-endings of the nerve of hearing are distributed.

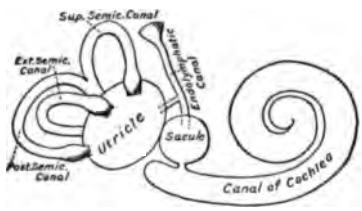

FIG. 131.—Membranous labyrinth of the right ear, viewed from the outer side. Semidiagrammatic.

987. The **semicircular canals** are three tubes which communicate with the vestibule by five openings. They extend arch-like above and behind the vestibule, and their position is such that each one is at right angles to the other two. They are known as the *posterior*, *vertical*, and *horizontal canals*. One end of each tube is dilated, forming what is known as an *ampulla*.[2] Two of the arches join before entering the vestibule, which is why there are five, instead of six, openings into the vestibule. The membrane of the ampulla is

[1] Called after the anatomist who first described this part of the ear.

[2] From the Latin *ampulla*—a globular vessel.

991. Auditory judgment, *i. e.*, the appreciation of the distance and position of a sounding body, is less accurate than visual judgment. The apparent distance of the sounding body is usually judged by the intensity of the sound; but, for this and for judgments of position, from whence the sound comes, the sense of vision is employed.

992. Function of the Semicircular Canals and the Vestibule.—The semicircular canals and the vestibule, though occupying part of the space of the inner ear and in direct communication with the cochlea, are not, it is thought, connected in any way with the sense of hearing. As the result of experiments on animals and observation of persons in whom this part of the ear has been destroyed it is assumed that it is connected with the maintenance of equilibrium. A man whose semicircular canals have been destroyed loses the power to rise from a recumbent position without falling. The exact nature of the action by which this part of the nervous mechanism performs its function is unknown, but the view that has found widest acceptance is that stimulation of the nerve-endings around the hair-cells results from movements of the head which set up movement in the endolymph of the canals. Movements of the head, it is thought, increase the pressure of the endolymph in the canal in the plane of which the head is moved. This pressure moves the hair-cells in the ampulla of that canal, the movements being furthered by the dragging action of the

lar branch of the auditory nerve is around the hair cells of the saccule, utricle, and the ampulla of the semicircular canals. The central termination is in masses of gray matter in the pons from which fibers extend to the cerebellum and to motor centers of the spinal nerves. No fibers have been traced into the cerebral hemispheres.

990. PHYSIOLOGY OF THE EAR.—The external ear serves to protect the internal ear from the entrance of foreign substances and to conduct wave sounds[1] to the tympanum. When the sound waves strike the tympanic membrane they set it in vibration; this moves the hammer; from the hammer the motion is transmitted over the anvil and stirrup to the membrane covering the oval window and starts the membrane vibrating. These vibrations set up movement in the perilymph by which it is thought some of the strings of the basilar membrane are set in motion, and each string that vibrates in some unknown way communicates its movement to the hair cells and through these to the nerve fibers at their base, through which the stimulus is conveyed to the brain, where it is interpreted. The nature of the stimulus, of course, depends primarily upon the nature of the sound causing it. It is generally believed that the cochlea is able to analyse sounds and to modify the nature of the impulse, but how it does this and how the different sounds affect the mechanism of the cochlea is not known.

[1] For description of the nature and origin of sound, see Glossary.

CHAPTER XXV

THE ORGANS OF GENERATION

Name, Location, Structure, and Purpose of the Female Reproductive Organs and the Uterine Ligaments. Nature, Purpose, and Causes of Ovulation and Menstruation. Nature and Time of Puberty and the Menopause. Nature of the Ova and the Spermatozoa. Disposal of the Ova. The Decidua. Development of the Impregnated Ovum. Nature and Purpose of the Amnion, Chorion, Placenta, Umbilical Cord. Nutrition of the Fetus. Fetal Circulation. Function, Situation, Structure, and Development of the Breasts. Factors Influencing the Development of the Breasts and the Secretion of Milk. Mechanism of the Secretion of Milk. Composition of Colostrum and Milk.

993. ANATOMY OF THE FEMALE ORGANS OF GENERATION—NAMES.—The female organs of generation are divided into an internal and an external group. The internal organs comprise the ovaries, the Fallopian tubes, the uterus, and the vagina. The external structures include the mons Veneris, the labia majora, the labia minora, the clitoris, the hymen, the vulvo-vaginal and urethral glands. Collectively, the external structures are known as the *vulva* or *pudendum*.

The Ovaries

994. SHAPE, LOCATION, ATTACHMENTS.—The ovaries are two almond-shaped glandular bodies,

situated one on each side of the uterus—but a slight distance from it—in the posterior fold of the broad ligament, behind and below the Fallopian tubes. Each ovary is attached by its anterior margin to the posterior layer of the broad ligament, by its outer extremity to a fimbria of a Fallopian tube, by its inner extremity to a short ligament—the ligament of the ovary—which connects it with the uterus.

Size. Each ovary is about 1½ inches in length, ¾ of an inch in width, ⅓ of an inch thick, and it weighs from 1 to 3 drams.

995. STRUCTURE.—The substance of the ovary consists of (1) a stroma or bed, comprised of white and yellow fibrous tissue, muscular tissue, blood-vessels, lymphatics and nerves; (2) Graafian follicles; (3) a covering of serous membrane that is continuous with the peritoneum.

996. GRAAFIAN FOLLICLES.—These are the sacs or vesicles which contain the ova or cells from which, when fecundated, a new being may be developed. The follicles, known also as vesicles and ovisacs, consist of (1) an outer transparent coat of fibrous tissue that is connected to the stroma of the ovary by a plexus of blood-vessels, and (2) an inner layer of nucleated cells. The vesicles, except the smaller ones, are filled with fluid in which an ovum is suspended. In each ovary of a young child there are about 36,000 vesicles of about $\frac{1}{800}$ to $\frac{1}{100}$ of an inch in diameter, but very few of them ever develop, the

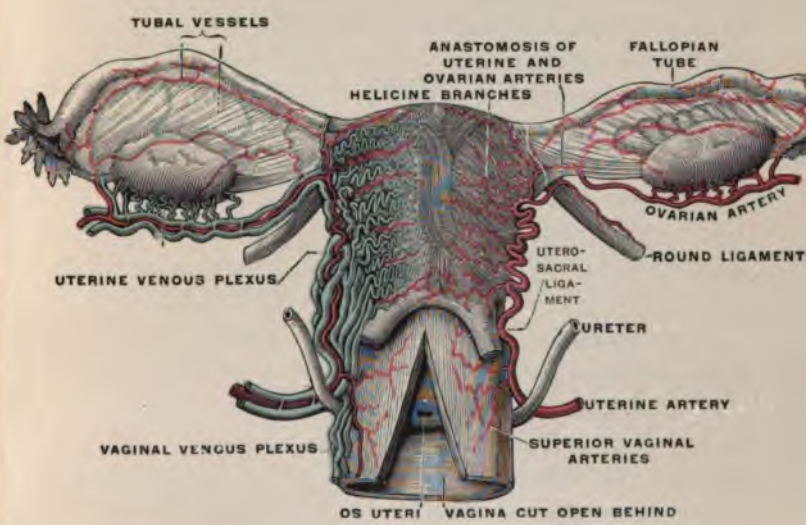

FIG. 132.—Vessels of the uterus and its appendages, rear view. (Gerrish

majority of them shrinking and disappearing. At the time of puberty the ovaries enlarge, become very vascular, and a number of follicles gradually increase in size, and approach the exterior of the ovary and project from its surface in the form of clear vesicles, $\frac{1}{20}$ to $\frac{1}{8}$ of an inch in diameter, being covered only by an exceedingly thin layer of the outer tissue of the ovary. When a vesicle is fully matured, it and the restraining tissue rupture and the contents of the vesicle—the fluid and ovum—are discharged. This gradual development and rupture of a follicle continues at regular intervals from puberty until the climacteric. The process is known as *ovulation*. One ovum is probably shed each month.

997. The Corpus Luteum.[1]—After the rupture of an ovisac and the escape of the fluid and ovum, there is an exudation of bloody fluid into the emptied sac. This fluid gradually clots and a cellular structure, with glandular characteristics, is developed in its interior from cells which line the follicle. This is known as the *corpus luteum*. If pregnancy does not occur, the corpus lutem disappears before the next menstrual period, but, in the event of pregnancy, the corpus luteum persists until the fourth or fifth month of gestation. It is now commonly considered that the corpus luteum is a gland with an internal secretion whose function is connected with menstruation and with the implantation of the ovum, should it become fertilized, and the subsequent

growth of both ovum and uterus in pregnancy. It is thought also that the secretion of the corpus luteum is concerned with, and possibly is, the internal ovarian secretion.

The Fallopian Tubes or Oviducts

998. *Number, Location.*—The Fallopian tubes, two in number, are situated in the free or upper margin of the broad ligament and extend between the ovaries and the upper angles of the uterus.

999. *Structure.*—The walls of the Fallopian tubes consist of three coats: (1) an external or serous coat, derived from the peritoneum; (2) a middle or muscular coat, which consists of a layer of longitudinal fibers and a layer of circular fibers; (3) an internal mucous coat which is arranged in longitudinous folds and covered with ciliated epithelium. It is continuous at its inner end with the lining of the uterus, and at the outer extremity with the serous lining of the abdominal cavity. This is the only place in the body where a serous and mucous membrane connect.

1000. *Size, Shape, Fimbriæ.*[1]—Each tube is about four inches long. At its point of attachment at the uterus it is exceedingly narrow, but it gradually increases in size so that at its distal end it is about $\frac{1}{8}$ of an inch in thickness. At its dis-

[1] From the latin *fimbriæ*—a fringe.

tal end each tube opens into the cavity of the abdomen and is surrounded by a series of fringe-like processes termed *fimbriæ*, one of which, longer than the rest, is attached to the ovary.

1001. *Purpose.*—The Fallopian tubes serve to convey the ova from the ovaries to the uterus. Just how the ovum when discharged from an ovary reaches the Fallopian tube is not known, but it is thought that the movements of the cilia on the fimbriæ and in the tubes set up a current that draws the ovum into a tube. It is considered probable that many ova discharged from the ovaries are not caught up by the fimbriæ, but remain, and become disintegrated, in the pelvic cavity, the products of disintegration being absorbed and carried away by the blood. Such a view explains the occurrence of *ectopic gestation.* After the ovum enters an oviduct it is carried to the uterus by the peristaltic action of the tube and the movement of the cilia covering its lining membrane. The nature and disposal of the ovum will be discussed in paragraph 1029.

The Uterus

1002. *Purpose.*—The uterus receives the ovum from the oviducts and, if the ovum becomes fecundated, retains it during its development. Later, when the fetus into which the ovum develops, is matured, it is expelled chiefly by the contraction of the uterine walls.

1003. *Shape, Size, Location.*—The uterus is a hollow, somewhat pear-shaped organ. In the virgin state it measures about three inches in length, two inches in width at its upper part, and one inch in thickness, and is situated in the pelvic cavity between the urinary bladder and the rectum. During pregnancy the uterus becomes enormously enlarged, measuring twelve inches or more in length, and eight to ten inches in width, and it extends into the hypogastric and lower part of the umbilical region. After parturition the uterus returns to almost its original size, but it is slightly larger than before pregnancy. In old age it becomes much smaller and atrophied.

1004. *Divisions.*—For convenience in description the uterus is considered as being divided into three parts, called the *fundus*, *body*, and *neck*. The fundus is the upper rounded portion, the body the central portion, and the cervix or neck the lower constricted part. At its juncture with the cavity of the body, the cavity of the cervix is so constricted that its sides are in apposition, as they are also at its external opening into the vagina. The upper constriction is called the *os*[1] *uteri internum*, and the lower one *os uteri externum*.

1005. *Structure.*—The walls of the uterus are thick and consist of three coats: (1) an external serous coat derived from the peritoneum (this coat is lacking on the anterior surface of the cervix); (2) a muscular coat; this forms the bulk of

[1] From the Latin *os*—an opening (plural ora).

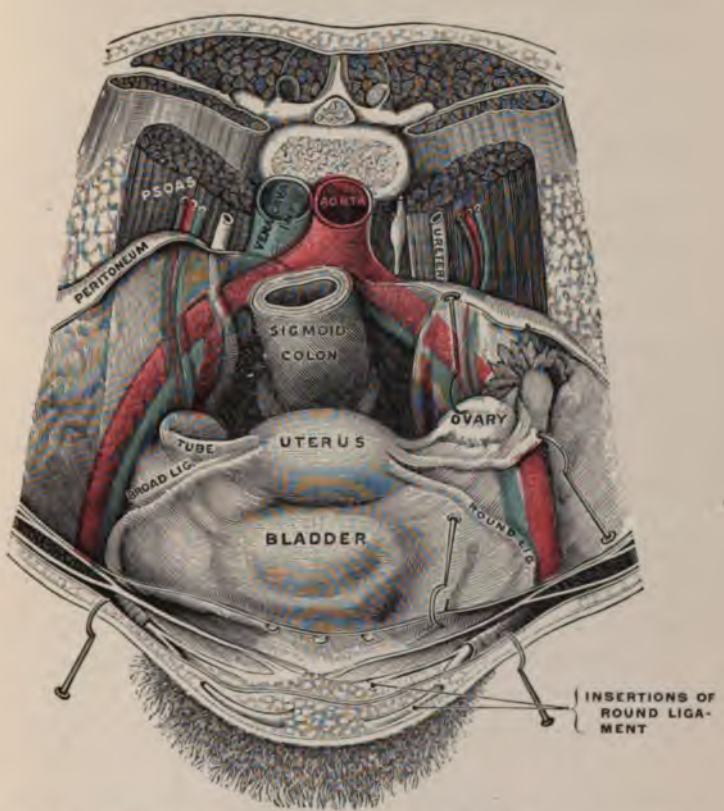

FIG. 133.—Female pelvic viscera, from above. The ovary and tube of the left side have been lifted out of place. (Gerrish.)

the uterine walls. It consists of layers of unstriped muscular tissue intermixed with areolar tissue, blood-vessels, lymphatic vessels, and nerves. The arrangement of the muscle fibers is very complex, and the vessels and nerves take a very tortuous course through the substance of the organ in order to prevent their being stretched as the uterus enlarges during pregnancy.

1006. THE LIGAMENTS.—The uterus is maintained in position by three pairs of ligaments named the broad, the round, and the utero-sacral ligaments.

The **broad ligaments** consist of two opposed serous sheets which are continuous with the peritoneum. They cover the anterior and posterior surfaces of the uterus and extend from the lateral border of that organ and the upper part of the vagina outward to the side walls of the pelvis where they merge into the parietal peritoneum. Between these two sheets of tissue constituting the broad ligaments the following structures are found: the ovaries and their ligaments, the Fallopian tubes, the round ligaments, also blood and lymphatic vessels, nerves and areolar and fatty tissue.

The **round ligaments** are two round cords composed of fibrous muscle and areolar tissue, blood-vessels and nerves. Each one is about five inches in length and extends from the upper angle of the uterus—a little below the attachment of the Fallopian tube—forward and outward through the

inguinal canal to the mons Veneris and labia majora, in the tissues of which it is lost.

The **utero-sacral ligaments** consist of smooth muscular fibers and serous membrane. They extend between the cervix and rectum and serve to hold the cervix and vagina to the sacrum.

1007. PERITONEAL POUCHES.—The peritoneum dips into a recess between the bladder and uterus and thus forms a small pouch which, when the bladder is empty, is occupied by coils of small intestine. This is called the utero-vesical sac. A similar though deeper sac is formed in like manner between the rectum and the upper part of the vagina and the cervix; it is called the *recto uterine* or *cul-de-sac of Douglas*.

The Vagina

1008. *Nature, Location, Size.*—The vagina is a membranous sac which encircles the lower portion of the cervix of the uterus and extends downward and forward to the vulva, behind the bladder and in front of the rectum. The length of its anterior wall is about 2 to 2½ inches and that of its posterior 2½ to 4 inches. It is constricted at its opening into the vulva, but becomes more dilated at its uterine extremity.

1009. *Structure.*—The vaginal wall is about ⅛ of an inch in thickness and consists of three coats: the outer one is of fibrous tissue; the middle one of muscular tissue, and the inner one of mucous

membrane. The mucous coat is disposed in transverse folds; this allows of the dilation of the vagina during parturition.

The External Organs

As previously stated, the external structures classed with the organs of generation in the female

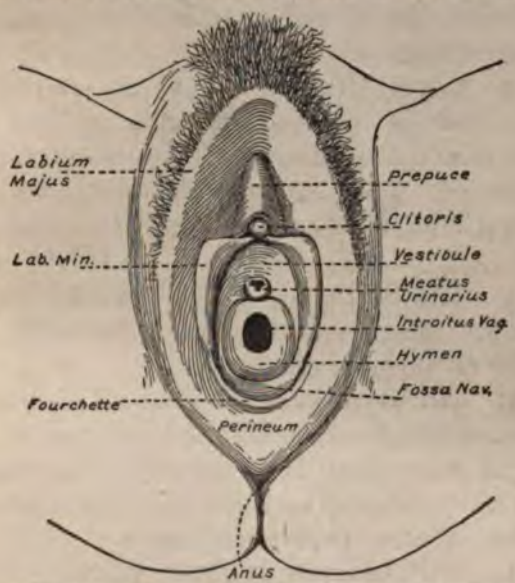

FIG. 134.—Vulva of a virgin. The labia have been widely separated to show parts situated between them. Foss. Nav., fossa navicularis; Int. Vag., introitus vaginæ; Lab. Min., labium minus; Vestib., vestibule.

are: the mons Veneris, labia majora, labia minora, clitoris, hymen, and the vulvo-vaginal and urethral glands.

1010. MONS VENERIS.—The mons Veneris is an eminence situated in front of the pubes, consisting of areolar, adipose, and fibrous tissue covered with skin and, after puberty, with hair.

1011. LABIA MAJORA.—These are two longitudinal folds of skin containing adipose and connective tissue. They extend from the mons Veneris in front to within an inch of the anus of the rectum behind.

1012. LABIA MINORA.—These are two longitudinal folds of modified epithelium. They are smaller than the labia majora, between which they are situated. They extend from the clitoris (see Fig. 134) downward and backward for about 1½ inches

1013. THE CLITORIS.—This is a small structure situated at the apex of the triangle formed by the junction of the labia minora.

1014. THE HYMEN.—This is a fold of mucous membrane which surrounds the lower part of the orifice of the vagina. Occasionally it completely covers the vulvo-vaginal opening. This condition is spoken of as an *imperforate hymen.*

1015. THE GLANDS OF THE VULVA.—These consist of the vulvo-vaginal glands or glands of Bartholin and the urethral glands. The former are two small glands situated one on either side the vagina. Their secretion lubricates the vulval canal. The urethral glands are found chiefly in the walls and floor of the urethra. They secrete mucus.

1016. THE PERINEUM.—The perineum is not usually classed with the organs of generation, but it is so closely connected with them, both anatomically and functionally, that it seems well to describe it here. It consists of bands of muscle held together with fasciæ and covered with skin. It bounds the external outlet of the pelvis and constitutes the floor of the genital canal. An important part of the perineum is the triangular portion which separates the vagina and rectum. This, though quite extensible, is frequently torn during parturition, and when the tear is of any extent and is not repaired, the vagina and uterus lose a support, and various abnormal conditions may follow.

Physiology of the Female Reproductive Organs

1017. *Purposes.*—The purposes of the female reproductive organs are: (1) the formation and development of the ovum, the cell which, if it becomes united with a spermatozoön—the fecundating cell developed in the testis of the male—will develop into a new individual; (2) the harboring and affording sustenance to the fetus—into which a fecundated ovum develops—until it is sufficiently grown to live outside the body.

1018. OVULATION.—As stated in paragraph 996 the ovaries contain in their substance at birth a great number of undeveloped Graafian follicles, some of which at the time of puberty enlarge and come to the surface of the ovary, and

from that time at regular intervals of about a month a follicle ruptures and discharges its ovum. This process of development of the follicle and its ovum and the rupture of the follicle is known as ovulation.

1019. PUBERTY.—Puberty consists in the maturation of the testis in the male and of the ovary in the female. The boy, at the time of puberty and for a short time before, grows rapidly, and owing to the rapid growth of the larynx and vocal cords marked changes occur in his voice. In the girl the time of puberty is marked by increased growth, development of the breasts and the appearance of the menstrual flow. In temperate climates the age at which boys usually attain puberty is about 15 years and girls 14 to 15 years. In warmer countries the age is somewhat younger and in cold countries older. The physical changes incidental to puberty are not developed suddenly, but take place gradually, during the course of several months, and the time in which they are occurring is known as the *period of adolescence.*

1020. THE MENOPAUSE OR CLIMACTERIC.—By the menopause or climacteric is meant the end of the period during which the Graafian follicles continue to develop in the ovaries, and, consequently, the time during which a woman is capable of bearing children. It is marked by the gradually lessening and, finally, the cessation of the menstrual flow, and the atrophy of the ovaries, tubes, uterus, and breasts.

1021. MENSTRUATION.—Menstruation is the periodical discharge of bloody fluid from the cavity of the uterus. Normally, it occurs at regular intervals of about 28 to 30 days, except during pregnancy and the period of lactation, from the time of puberty until the climacteric or menopause. The usual duration of the flow is from four to five days and the amount of blood lost is normally from four to six ounces. The fluid discharged consists of blood which does not clot, epithelium, and mucus. There is great difference of opinion as to whether or not any of the mucous membrane of the uterus is normally shed during the process of menstruation; the more common opinion at present is that it is not.

1022. CHANGES IN THE UTERUS, ETC., IN CONNECTION WITH MENSTRUATION.—Preceding the menstrual flow, the pelvic organs and the breasts are congested, and there is a more or less marked sense of general ill-being. The condition of the mucous membrane of the uterus undergoes changes preceding, during, and after menstruation as follows: five days before the process there is a rapid hypertrophy of the membrane; during menstruation there is a capillary hemorrhage and the epithelium undergoes degeneration and is cast off; during the seven days following menstruation, regeneration of epithelium takes place and the membrane returns to its normal size.

1023. RELATION OF OVULATION AND MENSTRUATION.—There have been many theories ad-

vanced regarding the relationship of ovulation and menstruation. Formerly many physiologists thought that menstruation was the result of a nervous reflex action occurring in connection with the development of a Graafian follicle. Others were of the opinion that the two phenomena were not at all dependent upon each other, owing to the fact that it was found that conception occasionally occurred before menstruation was established and after it ceased at the time of the menopause. At the present day the common view is that the menstruation is dependent upon the ovaries, but that the influence of the latter is exerted through the medium of the blood rather than through the nervous system. It is thought that an internal secretion is formed in the ovaries—some physiologists think by the yellow cells of the corpus luteum—which is carried by the blood to the uterus and that this secretion is responsible for the hypertrophy and congestion that precedes menstruation. It is not known, however, if the secretion of the ovary is entirely responsible for the menstrual flow or if this is in part induced by some inherent property in the uterine tissue. The supposition that the ovaries are responsible for menstruation arose from the fact that following operations in which the ovaries are removed menstruation ceases and the uterus becomes atrophied. The ovum, it is now thought, is discharged from the Graafian follicle some days before menstruation occurs.

1024. Reason for Menstruation.—The general view of the present day is that the congestion and hypertrophy of the uterine tissue preceding the menstrual flow is nature's preparation of the wall of the uterus for the reception of the ovum, should it become fertilized.

Physiology of Reproduction

1025. Types of Reproduction.—The reproduction of all living organisms is, as stated in Chapter I, brought about by cell division. There is, however, a fundamental difference in the methods of reproduction and according to this difference the types are said to be *asexual* and *sexual*. By asexual reproduction is meant that in which there is no union or fusion of what are known as *sex* or *germ cells*, but the cell increases in size, undergoes more or less complex internal changes, and then divides, giving rise to two cells. It is only very simple organisms, however, that are reproduced in this way. By sexual reproduction is understood that in which cell divisioning is preceded by the union of germ cells. The female sex cell is known as the *ovum*[1] and the male, as the *spermatozoön*[2] or *sperm cell*.

1026. Sex Cells.—The female germ cell or ovum, when matured, measures about $\frac{1}{120}$ of an

[1] From the Latin *ovum*—an egg.

[2] From the Greek *spermato*—a seed and *zōon*—an animal. Plural spermatozoa.

inch in diameter. It contains cytoplasm, a nucleus or germinal vesicle, and a centrosome. The cytoplasm holds what is known as *yolk*, which is food material, and the nucleus, a nucleolus or germinal spot, and a very important substance termed *chromatin*. The whole structure is enclosed in a membrane called the *zona radiata* or *zona pellucida*. The spermatozoön or sperm is about $\frac{1}{500}$ of an inch in length. It is rod-shaped. The end which contains the nucleus is called the *head* and the other the *tail*. The nucleus, like that of the ovum, contains chromatin material. Sperm cells are capable of independent movement and therefore, when the seminal fluid in which they are contained is discharged into the vagina of the female in the act of coitus they can travel upward and through the uterus and enter an ovum. Usually, only one spermatozoön enters an ovum, and only the head and the portion of the body containing the centrosome, the tail being cast off.

1027. CHROMOSOMES.—The chromatin material in both the ovum and sperm divides into a number of granular bodies termed *chromosomes*. The number of these varies in different species of animals, but is always the same for animals of like species, and the number formed in each of the sex cells is double that found in the other cells of the body. It is the chromosomes which contain the

hereditary material, *i. e.*, the substance by which the characteristics of the parents are transmitted to their offspring. The sex cells with their chromatin are set aside for their purpose of reproduction at a very early stage of the parent's embryonic life, and the only way in which the life of the individual in whom the cells are produced can influence these cells and, consequently, the offspring is by matter that can diffuse into them from the blood.

1028. Maturation of the Germ Cells.—The ovum, when liberated from the ovary, contains, as stated in paragraph 1027, double the number of chromosomes normal for the other cells of the animal producing them, and before it is ready for fertilization by a sperm cell this number must be reduced. The necessary reduction is brought about during the process termed *maturation*, in which the nucleus moves outward and, after a series of internal changes, divides into two parts, each part taking an equal number of chromosomes. One nucleus thus formed remains stationary and the other migrates farther to the surface of the ovum, where it remains temporarily as a minute protrusion. After a short time, both nuclei subdivide and each subdivision takes an equal share of chromosomes. One nucleus formed from the one which remained within the cell is pushed outward and the other returns to the center of the ovum. This is called the *female pronucleus*. The extruded nuclei are termed

polar cells. They soon disappear, as does also the centrosome, and the ovum is incapable of dividing unless it becomes fertilized by a male cell. The sperm cell also undergoes a process of maturation the essentials of which are similar to those occurring in the ovum, but it does not lose its centrosome. Thus, as the result of maturation, the spermatozoön and ovum each contain but half the number of chromosomes contained in the cells of the body tissues, but when a spermatozoön enters an ovum its remaining chromosomes make up the required number. Did the sex cells not discard some of their chromosomes each generation would have double the amount of chromatin in their cells, for in the cell divisioning to which the growth of the body is due the chromatin splits into the number of chromosomes normal for the tissues in the beginning, and these do not become equally divided between the two cells formed by partition, but they, like the nucleus containing them, each split in half and in this way provide the two cells with an equal amount of chromatin. It is not known why, in the germ cells, double the number of chromosomes normal for the tissue cells are formed at first.

SUMMARY.—It is only by fusion of the matured sperm and ovum that a cell which can divide is produced, for neither of these alone contains all the essentials for the process. They each have but half the normal number of chromosomes; the ovum contains cytoplasm with its food material, but it

has no centrosome; the sperm has no food material, but it has a centrosome, and perhaps other qualities, which give it the power of initiating cell divisioning in the ovum. It is thus said to *fertilize the ovum.*

1029. Disposal of the Ovum.—As stated in paragraph 1001, it is thought that after an ovum escapes from a ruptured Graafian follicle it is usually caught by the fimbriæ of a Fallopian tube, and then slowly forced through its channel by the motion of the cilia covering the membrane by which it is lined. If the ovum does not become impregnated it enters the uterus and is cast off, probably, in the menstrual flow. If, however, as it passes through the tube it comes in contact with the male element—the spermatozoön—segmentation or the process of cell division at once begins, and when the ovum reaches the uterus it becomes attached to the mucous membrane of that organ, usually in the upper part near the openings of the Fallopian tubes.

1030. The Decidua.[1]—The membrane lining the uterus is prepared for the reception of an impregnated ovum by the softening and congestion that precedes the menstrual flow. When in this condition it is known as the *decidua*, or *decidua vera*, and the point to which the ovum becomes attached is known as the *decidua serotina*[2]—this, later, develops into the placenta. A fold

[1] From the Latin *deciduus*—falling off and *vera*—true.
[2] From the Latin *serotina*—latest.

of the decidua vera gradually encapsulates the ovum, and this is known as the *decidua reflexa.*[1]

1031. DEVELOPMENT OF THE OVUM.— The union of the spermatozoön and ovum[2] usually takes place in one of the Fallopian tubes, and it is thought that it requires about eight days for the impregnated ovum to reach the uterus. During this time segmentation or cell division is going on, so that by the time the ovum reaches the uterus many thousands of cells have been formed, and also the sac enclosing them. The sac is known as the *amnion.* At first there is little apparent difference in the nature of the cells, but they soon divide into three distinct layers, and the cells of each layer gradually present marked distinctions and serve different purposes. Thus, from the outer layer called the *ectoderm*[3] or *epiblast*[4] are derived the ectodermic layer of the chorion and amnion (described in paragraph 1031), the epidermis, derma, nails, hair, the enamel of the teeth, the mammary and salivary glands, portions of the alimentary canal, the mouth, nasal passages, the nervous system and sense organs. From the middle layer—known as the mesoderm or *mesoblast*[5] —arise the bones, the muscular and connective

[1] From the Latin *reflexa*—turned back.

[2] The ovum and spermatozoön combined are usually considered as one cell, since neither one alone contains all the essentials necessary for cell division and growth.

[3] From the Greek *ektos*—outside and *derma*—the skin.

[4] From the Greek *epi*—upon and *blastos*—a germ.

[5] From the Greek *mesos*—middle, etc.

embryo gets its nutrition from the mother's blood. That it can do so is due, during the first four months of its development, to the presence of the chorion, and afterwards to that of the placenta and umbilical cord.

1037. RESPIRATION.—During intra-uterine life, the lungs are in a collapsed condition and do not function, and the fetus gets its oxygen supply and gives up its waste matter through the same channels as it receives its nutrition. The blood flowing from the fetus to the uterus—consequently the blood carrying waste matter from the fetus—is contained in the arteries of the cord. The blood conveying nutritive material and oxygen from the mother to the fetus is contained in the veins. As stated in the preceding paragraph, there is no anastomosis between the uterine and placental vessels, the interchange of material between the blood of the two sets of vessels being the result of osmosis and diffusion.

1038. DIFFERENCES IN THE ORGANS OF CIRCULATION IN THE FETUS AND AFTER BIRTH.—In the fetus there are certain structures necessary to the performance of its circulation that are of no use after respiration is established and the blood no longer flows through the vessels of the umbilical cord and placenta. These are as follows: (1) an opening between the right and left auricles of the heart, known as the *foramen ovale*, which permits of the passage of blood from one auricle to the other. This, normally, closes at birth; failure to

and the external genitals are sufficiently formed to show the sex. It is known now as a fetus. At the completion of twenty-six weeks' development it is possible for the fetus to live outside the mother's body, but if it is born before term, *i. e.*, nine lunar

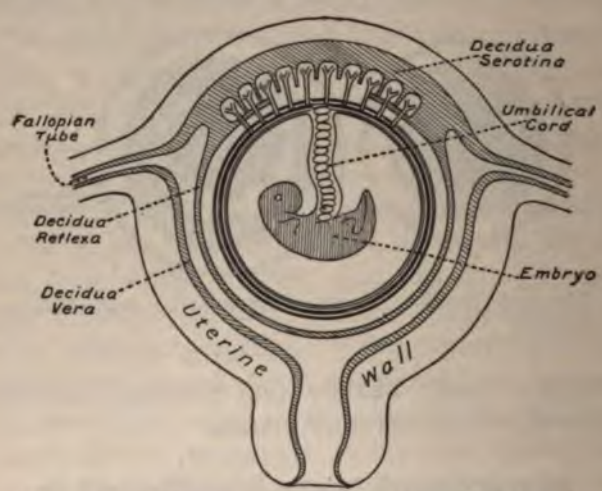

FIG. 136.—Diagram of gravid uterus, showing formation of deciduæ and placenta.

months after conception, it is likely to be very fragile.

1033. THE AMNION.—While in the uterus, the fetus is surrounded by a membranous sac known as the amnion or amniotic sac.[1] Except at the point of attachment to the uterine wall, the amniotic sac consists of three layers: an inner

[1] From the Greek *amnion*—a bowl.

serous layer, a middle layer called the chorion,[1] and an outer layer made up of the decidua reflexa. The inner layer secretes a fluid known as the *amniotic fluid* or *liquor amnii*. The outer surface of the chorion is covered with small, shaggy projections, like fringes of moss, called *chorion villi*, which, especially at the point of attachment to the uterus, become very vascular by the development in them of loops of capillaries. The function of the chorion is to hold the embryo to the uterus and to absorb nutrient matter for the fetus from the mother's blood until the placenta is formed; also, at its point of attachment to the uterus it enters into the formation of the placenta. The other purposes of the amniotic sac and its contained fluid are: To protect the fetus from injury by jars due to the mother's falling or receiving a blow on the abdomen, etc.; to allow the fetus freedom of movement; to distend the cervix of the uterus during labor, and when the sac ruptures setting free the liquor amnii, as normally it does shortly before the child is forced from the uterus, by the contraction of its walls, the discharged fluid lubricates and washes out the vaginal canal.

1034. THE PLACENTA.—The placenta is formed during the second and third month of gestation. It is fully developed by the fourth month, but it increases in size as pregnancy advances, and at

[1] From the Greek *chorion*—skin, leather.

It will be remembered that the amnion and chorion are derived from the outer layer of cells arising from the impregnated ovum.

the end of a normal pregnancy it measures about eight inches in diameter and one inch in depth at its thickest part, the center, and weighs one to one and a half pounds. The placenta consists almost entirely of blood-vessels held together with connective tissue. The vessels form loops that project into the uterine tissue and interlock with uterine blood-vessels, there is, however, no anastomoses between the uterine and placental vessels.

1035. THE UMBILICAL CORD.—There develops at the same time as the placenta, a cord-like structure known as the umbilical cord. It consists principally of two arteries and one vein surrounded by a gelatinous substance known as *Wharton's jelly*. The average length of a cord is about twenty inches. It is continuous at one end with the placenta and at the other end with the fetus, entering the abdomen of the latter at a point called the *umbilicus* or *navel*. Its purpose will be discussed in the next paragraph. The placenta, cord, membranes and part of the decidua are, normally, expelled from the uterus shortly after the birth of the fetus. The remaining portion of the decidua is cast off gradually during the days following parturition, in what is known as the *lochia*, and a new mucous membrane gradually replaces it.

1036. NUTRITION OF THE FETUS.—At the time of fertilization, the ovum contains a small amount of nutrient material in its cytoplasm, but only about sufficient to last until it becomes attached to the decidua of the uterus. After that time the

embryo gets its nutrition from the mother's blood. That it can do so is due, during the first four months of its development, to the presence of the chorion, and afterwards to that of the placenta and umbilical cord.

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do so results in what is known as a *blue baby*, and the infant rarely lives many months; (2) a duct between the aorta and the pulmonary artery called the *ductus arteriosus*, which closes as soon as the child breathes; (3) a short vessel connecting the umbilical vein with the ascending vena cava, called the *ductus venosus*; (4) two arteries, called the *hypogastric arteries*, which, arising from the internal iliacs, pass from the abdomen through the navel and run into the umbilical cord where they are known as the *umbilical arteries*. The hypogastric arteries and the ductus venosus close as soon as the cord is cut, and gradually atrophy, so that they are simply fibrous cords between ten and fifteen days after birth.

1039. FETAL CIRCULATION.—The blood containing oxygen and nutrition for the fetus is carried to it by the umbilical vein and passes into the ascending vena cava partly through the liver, but chiefly through the ductus venosus, which, as stated in the preceding paragraph, connects the umbilical vein with the vena cava. From the ascending vena cava the blood flows into the right auricle and thence through the foramen ovale into the left auricle, and on into the left ventricle, and onward into the aorta. From the aorta some of the blood, following the course normal after birth, goes to the head and upper extremities, and some to the lower extremities. The blood which goes to the upper part of the body returns through the descending vena cava

to the right auricle again, but instead of passing into the left auricle as before, it flows into the pulmonary artery and some of it passes to the lungs—to supply them with nutrition only—and some into the aorta through the ductus arteriosus. Thence it passes to the lower extremities and abdominal viscera. In going to and from the lower part of the body the blood follows the same course as it does after birth until it reaches the internal iliac arteries. From these arteries the greater part of the blood passes to the hypogastric arteries and so into the umbilical arteries and onward to the placenta; but a small amount passes back into the ascending vena cava, and, mingling with the vitalized blood returning from the placenta, again makes the circuit of the body.

Accessory Organs of Generation

The two mammary glands or breasts are classed as accessory organs of generation.

1040. *Purpose.*—The mammary glands serve to secrete the milk which the young infant needs for its sustenance.

1041. *Situation.*—The breasts are situated, one on either side, on the anterior wall of the chest between the third and seventh ribs. They are attached to the pectoral muscles by a meshwork of fibrous tissue.

1042. *External surface.*—The external surface of each breast consists of: (1) an area covered with

skin; (2) an areola, the small circular area of tinted skin on which are small projections formed

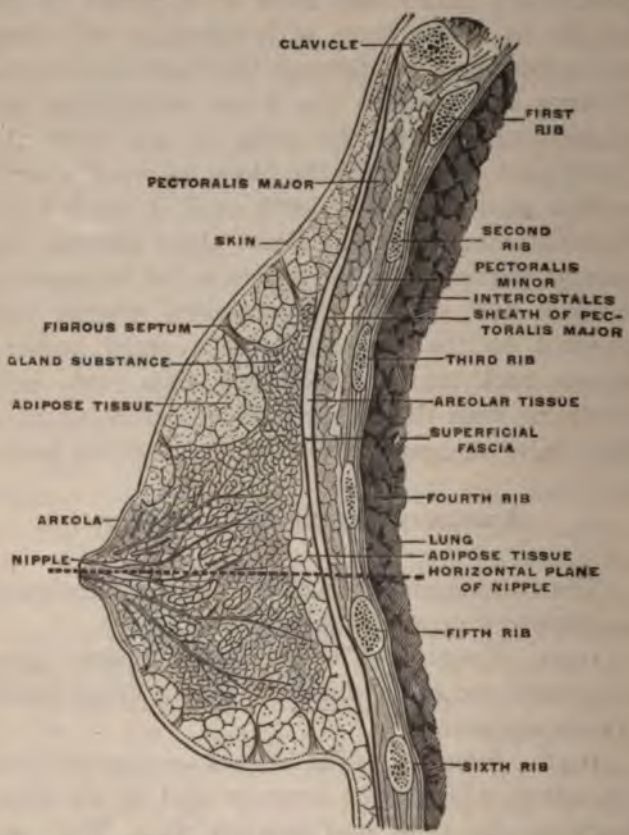

FIG. 137.—Right breast in sagittal section, inner surface of outer segment. (Gerrish.)

by minute secreting glands; (3) a nipple, a papilla projecting from the center of the areola and having

at its summit the openings of the milk ducts. It consists of areolar tissue with some unstriped muscular fibers and numerous blood-vessels.

1043. *Structure.*—Each breast consists of some fifteen or twenty main glands formed by the union of smaller (lobular) glands. The main glands or lobes are separated from each other by walls of fibrous and fatty tissue. Each one is provided with an excretory duct which, as it approaches the top of the breast, dilates and forms a small reservoir in which, when the gland is active—*i. e.*, during the months of lactation—milk can be stored. The breasts are supplied with a large number of blood and lymphatic vessels and nerves.

1044. *Development.*—At the time of puberty the mammary glands increase in size, but this enlargement is due chiefly to the development of their connective tissues, the glandular tissue remaining undeveloped and functionless unless conception takes place. When conception occurs the glandular tissue gradually develops; the breasts become enlarged; the areola assumes a deeper hue, and toward the end of pregnancy a small amount of a fluid known as colostrum is secreted. After delivery the secretion of colostrum is increased and its composition gradually changes to that of milk.

1045. Factors Influencing the Development of the Glands and the Secretion of Milk.—Formerly it was thought that the development of the mammary glands was influenced by some nerve connection between the glands and the

ovaries and uterus. The present theory is that their primary development is influenced by the internal secretion of the ovaries, for if the ovaries are removed the glands do not develop, or, if they are developed before the ovaries are removed they become atrophied, as they do after the menopause. The development of the glandular tissue, it is thought, is due to some chemical substance, the nature of which is as yet unknown, that is produced as the result of the metabolism of the fetus, and absorbed by the blood and carried to the glands. This substance, it is thought, though promoting the development of the glandular tissue interferes with its secreting, as it is not until the fetus has been expelled from the uterus that active secretion commences, and if a new conception occurs during the months of lactation the character of the milk changes and its secretion soon ceases. The stimulus causing the secretion of milk arises, it is thought, from the emptying of the ducts; one reason for this supposition being that when a woman does not nurse her infant the secretion of milk soon ceases and the breasts return to the size they were before pregnancy. The nature of the stimulus is as yet unknown. Also, the secretion of milk is to some extent influenced by the nervous system, strong emotion from any cause interfering with its secretion; but this is supposed to be due chiefly to changes in the vaso-motor system which interfere with the blood supply to the glands.

1046. Mechanism of the Secretion of Milk. —The secretory portion of the glands composing the breasts are, like all other secretory glands, lined with secretory cells, and some of the constituents of the milk, the water, salts, and probably sugar are secreted by these cells from the blood; but the proteids and fats, it is thought, are derived as the result of the disintegration of the cells themselves. The sugar in the blood is glucose and that in the milk lactose; therefore if the latter is derived from the former it must undergo some slight chemical changes, either during or after secretion.

1047. Composition of Colostrum and Milk. —Colostrum is a thin, yellowish liquid composed of:

Proteids	5.71	per cent.
Fat	2.04	" "
Sugar	3.74	" "
Salts	0.28	" "
Water	88.23	" "
	100.00	" "

The milk of every animal is adapted to suit the requirements of its young, and human milk differs in some respects from that of all other animals. The relative proportion of its fluid and solids varies according to the time of lactation—the milk being more dilute at the first. The comparative proporton of the constituents of human and cow's milk can be seen in the following table:

	Human Milk.	Average Cow's Milk.
Proteids	1– 2%	4%
Fat	3– 4%	3– 4%
Lactose	6– 7%	4·5%
Mineral	1– 2%	·7%
Water	87–88%	86–87%

1048. Other differences in the two milks that must be considered when cow's milk is used for young infants are: (1) the proteid of human milk is two-thirds lactalbumin and one-third caseinogen and that of cow's milk is five-sixths caseinogen and one-sixth lactalbumin; (2) human milk coagulates in small flocculent curds and cow's milk in large firm masses. This difference in curding is partly due to the smaller amount of caseinogen in human milk and partly to the difference in the reaction of the two milks—cow's milk being more nearly acid than human milk.

CHAPTER XXVI

DEVELOPMENT. SENESCENCE. PHYSIOLOGY OF SLEEP

Normal Rate of Development—Weight, Height, Muscular Strength, Bones, Glands, Skull, Brain, Special Senses, Mental Development, Speech. Changes Occurring in the System During Senescence. Supposed Causes of Senescence. Why Sleep is Necessary. Theories for Causation of Sleep.

Normal Rate of Development

1049. *Weight.*—The average weight of male infants at birth is from about 6 to 8 pounds, and the average weight of female infants from 5½ to 7 pounds. During the first week after birth there is usually a slight loss in weight, but from that time there should be a steady and fairly regular daily increase of ⅔ of an ounce to an ounce during the first five months of life, and in the seven following months ½ to ⅔ of an ounce. Thus an infant should have doubled its birth weight by the end of five or six months and trebled it at between twelve or fifteen months.

1050. *Height.*—The average length of male infants at birth is about 19.6 to 20 inches, and that of female infants 19.1 inches. The average in-

crease of growth during the first month of life is about 1¾ inches; during the second month 1½ inches; from the third to fifteenth month ½ to ¾ of an inch per month. Thus during the first year there is, normally, an increase of about 8 inches in height; during the second year about 3½ inches, and during the third year 3 inches. From the above figures it can be seen that the most rapid increase in growth takes place during the first months following birth. After the third year a steady decrease in the rate of growth takes place until the time of the second dentition[1]—between the sixth and ninth years—when there is, for a time, a slight acceleration, and again in the period of adolescence when, as stated in the preceding chapter, there is a rapid increase in stature and general physical development. After puberty, growth takes place slowly, and gradually ceases.

1051. *Muscular Strength.*—At birth, the muscles of the hands and arms seem to have the greatest strength. The muscles of the neck are, usually, not sufficiently developed to allow the infant to hold up its head until three months after birth, and, generally, it is six or seven months before those of the back are strong enough to allow of an infant's sitting up. The muscles of the viscera, also, only become strengthened gradually, consequently, the peristaltic action of the stomach and intestines is weak, especially during the first two years of life. For this reason the former can

[1] The development of the teeth was described in Chapter V.

do little toward the breaking up of food material, and defective digestion or constipation quickly results in an accumulation of gas in the stomach and intestines.

1052. THE BONES.—At the time of birth the bones contain a large amount of cartilaginous material and are easily bent. This condition is of special importance to the bones of the leg. These, at birth, are usually crooked, owing to the fact that while in the uterus the fetus generally has its legs drawn up and turned inward. In order to correct this condition, free play of the legs, which will improve the circulation and strengthen the muscles, is imperative, but the average child must not be encouraged to walk until about twelve months of age, the proportion of mineral matter in the bones being, until that time, too small to allow of their being sufficiently strong to bear the weight of the body for any length of time without bending.

1053. GLANDS.—The action of the glands which manufacture the digestive juices, especially the salivary glands and pancreas, is very feeble during the first two or three months after birth, and the saliva contains little or no ptyalin—the ferment which digests starch—until the eighth month. The lachrymal glands are not sufficiently developed to shed tears until the third or fourth month. The sebaceous glands are active even before birth, as is shown by the thick coating of sebaceous matter—the *vernix caseosa*[1]—that covers

[1] Described in Chapter XXV.

the skin of the infant at birth. The thymus gland —see Chapter XVI—is large at birth and increases slightly in growth until the end of the second year, when it attains its maximum size and remains the same, it is thought, until puberty, when it becomes atrophied. The liver is proportionately large in the new-born baby. This is believed to be due to its receiving more freshly vitalized blood than the other glands and organs during intra-uterine life. The kidneys are developed and function before birth, as is shown by the presence of urine in the bladder at the time of birth, and the finding of traces of urine in the liquor amnii.[1]

1054. THE SKULL, BRAIN, AND MENTAL DEVELOPMENT.—At birth the skull is proportionately large and it increases in size considerably during the first year of life, and then more slowly up to the seventh year, when it has attained nearly its full growth. The size of the brain does not increase as rapidly as the skull, for it only reaches its maximum of physical development about the thirtieth year. The rate and degree of the functional development of the brain is as little in keeping with its physical development as is the latter with the growth of the skull, and it depends upon such factors as heredity, environment, study, health. In some individuals intellectual development continues long after physical growth has ceased; in others mental growth is arrested long

[1] Described in Chapter XXV.

before physical. At first the brain and other nerve centers work automatically and by reflex action only, and usually the first sign of anything like intelligence does not occur until between the third and fourth months, when a normal infant begins to recognize and remember people and things that it sees frequently. It is not, however, until the third year that the memory centers begin to be at all well developed. The emotions, imagination, and imitative faculties are developed long before the powers of reasoning and judgment, so that until a child is at least seven years of age he can be more readily taught by example, than by reasoning, and more easily controlled by appeal to his sympathy and affection, than by reasoning.

1055. SPECIAL SENSES: *Speech.*—The senses of touch and taste are present at birth, but hearing does not seem to be developed until a few days later, and the sense of vision is apparently not very acute until about the third week. Many children learn to say short words about the end of the first year, but usually they do not begin to try to express their wants in speech until between the second and third years, and many perfectly normal children are even older before they begin to talk.

1056. SENESCENCE.[1]—After puberty, physical development goes on slowly for a few years until maturity is reached, the time varying in different

[1] From the Latin *senescens*, pr. par. of *senesco*—to become old.

individuals, and then very, very gradually at first, but nevertheless surely, retrogressive changes begin. The bones become brittle from an increased deposit of inorganic salts; cartilage, ligaments, muscles lose their elasticity. The glandular tubules of the stomach and intestines become diminished in number; the glandular tissue of the ductless glands is decreased and the fibrillar tissue increased, and consequently the secretion of digestive and internal secretions become diminished. The walls of the arteries lose their elasticity and become hardened. The hair loses its pigment and becomes white, and the skin in some parts of the body grows wrinkled. The special senses of taste, smell, hearing, and vision lose their acuity. In women at about the age of forty-five, and somewhat later in men, the organs of generation become atrophied and lose their power of functioning, and the progress of the retrogressive changes thereafter become more marked. This condition of retrogression is known as senescence. Two common reasons advanced for the defective metabolism characteristic of the senescence are (1) lack of nutrition of the tissues due to the hardening of the arteries—arterio-sclerosis—and (2) the lack of internal secretions resulting from the degeneration of the ductless glands and other organs furnishing such secretions. These beliefs have given rise to the sayings: "A man is as old as his arteries," and "A man is only as old as his ductless glands." Arterio-sclerosis and degeneration of the glands

take place comparatively early in some individuals, and some of the more common causes for this are: certain diseases—especially syphilis, rheumatism, heart, and kidney diseases; chronic poisoning by the continued overuse of alcohol and other drugs, as morphine, cocaine, etc., or the products of putrefaction resulting from over-feeding; under-feeding; exposure to extremes of temperature; over-work; continued mental strain; heredity.

The Physiology of Sleep

1057. WHY SLEEP IS NECESSARY.—All parts of the body that are the seat of active work require periods of rest. Some parts, as the heart, lungs, and muscles concerned in respiration, cannot stop work for any length of time, therefore short regular intervals of rest have been provided for them in the midst of their activity. Such alternate periods of rest and work would be impossible, however, for the brain, and though the voluntary muscles and the viscera are less active at some times than at others, the period of activity, and consequently their metabolism with the production of waste, is far in excess of their intervals of rest and repair. Hence the necessity for the period of unconsciousness and repose known as sleep, during which muscular tension is relaxed, and even those organs which must continue their action do so at a slower rate.

1058. CAUSE OF SLEEP.—The cause, or causes,

of sleep are as yet unknown. Three of the theories advanced are as follows:

(1) That it is the result of an accumulation of fatigue poisons within the system. As stated in Chapter VI, muscular contraction results in the formation of acids and other waste products known as fatigue poisons which, after being further oxidized, are eliminated from the system in the form of CO_2, H_2O and urea (CON_2H_4), etc. During waking hours, however, especially when an individual is very active, the fatigue poisons are formed quicker than the further oxidation necessary to transform them to CO_2, etc., and their removal can take place; consequently they accumulate in the system, and by their action cause a loss of irritability of the central nervous system. This lack of nervous irritability, it is thought, induces sleep, especially when the surroundings are dark and quiet so that stimulation of the sensory nerves is lessened.

(2) Sleep is said to be due to anemia of the brain. As the result of experiments it has been found that during sleep there is a lessened flow of blood through the brain; in other words the brain is anemic. Many authorities, however, consider this condition the result, and not the cause, of sleep. Those who consider it the cause of sleep believe that it is due to changes in the activity of the vaso-motor system. Thus, they think that the continual exposure to sensory stimuli, to which the body during waking hours is subjected, and

the constant activity of the brain keep the vasoconstrictor center constantly active, in consequence of which the vessels of the skin are more or less constricted and those of the brain relaxed. As the result of this constant, though varying activity, the center becomes fatigued and its activity lessened; consequently, the peripheral vessels lose their tone and accommodate a greater supply of blood, thus leaving so little for circulation in the brain that it cannot easily remain functioning. The drowsiness that follows efforts to study or to do other mental work after eating a heavy meal is an example of the result of anemia of the brain on the functioning power of that organ. The cause of the anemia was explained in paragraph 578.

(3) That both fatigue poisons and anemia of the brain are responsible factors. It is thought possible that the conditions produced in the nerve centers by fatigue poisons, absorbed from the active tissues by the blood, interfere with the stimulation of the nerve centers and among others those which maintain normal arterial tone. Lessening of arterial tone results in dilation of the vessels and consequent slowing of the circulation through the brain. The exact nature of the changes which the fatigue poisons produce in the nerve centers is not known; one theory advanced is that the dendrites of the neurones retract toward their cell bodies and away from the axons of neurones with which they are in synaptic junction and, in

consequence of this retraction, the transmission of impulses is interfered with.

1059. DREAMS.—The unconsciousness which we term sleep, it is thought, often exists in different degrees in different parts of the brain, and dreams, it is believed, are due to certain memory centers in the brain remaining partially active while the rest of the brain is asleep.

GLOSSARY

ABDUCTION, drawing or leading away; movement from the median line.

ACID, as adjective: sour; as substantive: an acid is a substance, having the following properties: All acids contain hydrogen; if they lose this element they cease to be acids. They will combine with bases to form salts, and in doing so part with their H. They turn blue litmus[1] and methyl[2] orange red. Acids may be gases, liquids, or solids; *e. g.*, carbonic acid is a gas; sulphuric acid, a liquid; salicylic acid, a solid.

ADDUCTION, drawing to; the drawing of one part of the body to another.

AËRATE, to subject to the action of air; to oxygenate.

AFFERENT, bringing or conducting to.

AGGREGATION, the act of collecting together, or the state of being so collected or massed.

ALBUMINS, certain substances containing nitrogen that are soluble in water, in dilute saline solutions, and in concentrated solutions of sodium chloride and magnesium sulphate. They are precipitated by saturating their solutions with ammonia sulphate. They are coagulated by heat and acid. Examples are: serum albumin of blood; egg albumin; the lactalbumin of milk.

ALIMENT, to furnish with food.

ALIMENTARY, pertaining to aliment or food.

ALKALI, a substance that is capable of neutralizing acids. Alkalies turn red litmus blue; turmeric brown; and most purple dyes of vegetable origin green. When combined with fats they form soaps. They have a salty taste.

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[1] Litmus is a liquid substance obtained from a species of lichen.

[2] Methyl orange is a yellowish coal-tar product.

ANABOLISM, a putting together; constructive metabolism; the opposite of katabolism.

ANALYSIS, the separation of anything into its constituent elements for the purpose of investigation.

ANASTOMOSE, to join or blend together mouth to mouth.

ANESTHETIZE, to produce anesthesia, *i. e.*, a state of insensibility.

ANTIPYRETIC, a medicine given to reduce fever.

APHASIA, a loss or impairment of the power of speech. When due to loss of memory of how to say some words, it is known as *motor aphasia*. When due to disturbance of the parts of the brain concerned with the memory of written or spoken words it is known as *sensory aphasia*.

ARBORIZATION. Tree-like branches.

ARTERIO-SCLEROSIS, hardening of the arteries.

ARTICULAR, pertaining to a joint.

ASH, the residuum left after the burning of anything combustible.

ASSIMILATION, to convert into a substance similar to that operating upon it; thus, the animal cells have the power of converting the material they take from the blood into substances like themselves.

ATOM, the usual definition of an atom is "the smallest particle into which an element can be divided." But recent researches have led to the supposition that atoms are not the smallest bodies, but that they can be broken up into still smaller particles, to which some authorities have given the name of *electrons*, and describe as "an electric charge in motion—a unit or atom of negative electricity."[1]

ATROPHY, a wasting of the body or any of its organs as the result of disease or old age.

AUGMENTATION, the act of augmenting or increasing.

AUTO-INTOXICATION, poisoned by toxic—poisonous—substances produced within the system.

AUTOMATIC (as used in physiology), carried on unconsciously.

AUTOPSY, examination of the body after death.

AXIAL ROTATION, rotation of the body around its axis—*i. e.*, a straight line, real or imaginary, around which a body revolves.

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[1] *Scientific Ideas of To-day*, page 51. Charles R. Gibson. T. B. Lippincott Co.

BASE (chemistry), a substance which unites with an acid to form a salt; the alkalies are bases.

BICONCAVE, concave, *i. e.*, hollowed out on both sides.

BICONVEX, convex, *i. e.*, rounded outward on both sides.

BICUSPID, having two points or flaps.

BOLUS, lump.

BRACKISH, salty.

CALCULI, plural of calculus, a stone.

CALIBER, the diameter.

CAPSULE, a small case or receptacle.

CATALYZER, a substance which hastens chemical reactions but does not itself enter into the reaction.

CELLULOSE, the fibrous and woody part of plants. Its chemical composition is similar to starch.

CENTRIFUGAL, spreading outward.

CENTRIPETAL, having a tendency to, or causing to, approach the center. The opposite of centrifugal.

CHEMICAL AFFINITY, the agency which causes substances to combine, and which holds them together when combined.

CHEMICAL REACTION, when a substance undergoes a chemical change there is said to be a chemical reaction. By a chemical change is meant a change that involves an alteration in the nature of the substance. A chemical change is the opposite of a physical change, which does not involve a change in the composition of the matter. For instance, if cane sugar is dissolved in water it is a physical change, because the chemical composition of the sugar is not changed, as can be proven by allowing the water to evaporate, when the sugar will be seen again just as it was before being dissolved. If, however, the sugar solution is boiled with acid, the sugar will be changed to glucose, a substance somewhat different to cane sugar, and in this case a chemical change or reaction has taken place.

CHOLESTERIN, a crystallizable, monatomic alcohol found in small quantities in the protoplasm of all cells, and more especially in nervous tissue, blood corpuscles, and bile. Its origin and function in the animal body are not known, but it is thought it may be concerned in tissue formation.

COALESCE, to grow together.

COLLOID, a non-crystallizable organic substance.

COLLOIDAL, of the nature of colloids.

COMBUSTION, burning. (*See* Oxidation.)

COMMISSURE, a joining together.

COMPONENT, part of a compound body.

CONCUSSION, the act or state of being dashed violently against another body. Concussion of the brain—shock or agitation of the brain.

CONDUCTION, the transfer of force from one part to another.

CONDUCTION of heat, the transmission of heat in matter by invisible molecular motion, the molecules passing their motion along from one to another within the body (*see* Molecular Motion). Metals are the best heat conductors; organic substances, such as wood, paper, and cloth, are poor conductors; glass, also, is a poor conductor. Solids are better heat conductors than liquids, and liquids than gases.

CONGENITAL, existing from birth.

CONSTRICTION, a narrowing or drawing together, a stricture.

CONTIGUOUS, adjacent, near.

CONVECTION, the act or process of conveying from one part to another.

CONVECTION CURRENTS: when any portion of air is heated it expands and becomes less dense than the cooler parts, which, acted on by gravity, sink and crowd the warmer parts upward. The currents of air established in this way are called *convection currents*. Distribution of heat and ventilation are accomplished mainly through the agency of convection currents.

CONVERGE, to join at a point.

CONVEX, curved outward.

CONVOLUTED, twisted.

COUNTER-IRRITANTS, agents, such as irritating drugs that, by producing irritation and consequent vascular dilatation in a part, will relieve congestion in another part; *e. g.*, a mustard foot-bath will relieve congestion in the throat.

DECIDUOUS, not permanent, shedding.

DECIDUOUS TEETH, the temporary teeth.

DECUSSATE, to cross in the form of the letter X.

DEPLETE, to empty; to deprive of strength.

DIAGNOSIS, determination of a disease by its symptoms.

DIALYSIS, the separation of crystallizable from non-crystallizable or colloid substance by means of a porous membrane. The

DIALYSIS—*Continued*
former will pass through a permeable membrane quicker than the latter, and, also, crystallizable substances will pass through membranes that colloidal substances cannot penetrate.

DIAPEDESIS, the passage of the blood-corpuscles through the capillary walls without rupture of the latter.

DIFFUSE, to spread out on every side.

DIFFUSION OF GASES: if a vessel, room, etc., is filled with two or more gases, the gases, even if they are of different densities, will diffuse and intermingle, so that in time each gas will be distributed uniformly through the whole space.

DISINTEGRATION, a breaking apart.

DISTAL, distant from the center; *e. g.*, the extremity of a bone farthest away from the point of attachment, or an organ comparatively distant from the center of the body.

DORSAL, the back.

ECTOPIC, out of place.

ECTOPIC GESTATION, the name given to pregnancy when the fecundated ovum, instead of entering the uterus, either remains in a Fallopian tube or falls into the abdominal cavity.

EFFERENT, to carry outward.

EMACIATION, a wasting away; thin.

EMBRYONAL, pertaining to an embryo.

EMULSION, a milk-like preparation of oil and water.

ENERGY, operative power; the capacity for doing work.

ENERGY—KINETIC, energy engaged in producing motion, etc.

ENERGY—POTENTIAL, latent energy; stored energy; *e.g.*, plants put CO_2 and H_2O together, forming other more complex compounds which are poorer in O and with a great affinity, especially the fats, for that element. To do this, energy is required, and this energy plants get from the sun, which is either directly or indirectly the source of all energy. The energy thus derived is stored up within the plant and is called *potential* or *latent energy*. When the products of digested food are oxidized in the body, this energy is liberated and becomes once more kinetic or work energy that produces heat, and the power that keeps all the internal organs and metabolism active, as well as the power to perform

ENERGY—POTENTIAL—*Continued*
external work. And the sum of the kinetic energy thus evolved will be equivalent to that derived from the sun.

EVAPORATION, the act or process of resolving into vapor. Evaporation may be visible to the eye; *e. g.*, the steam issuing from the spout of a kettle; the fog rising from the surface of a lake. Or it may be invisible, as the evaporation of sweat from the surface of the body. For the production of evaporation heat is necessary. It requires about 0.5 calory of heat for the vaporization of one gram of water, and unless heat is supplied, as, for instance, the fire which causes the water in the kettle to vaporize, it will be taken from near objects. Thus, the heat necessary to vaporize the sweat is taken from the body.

EXTIRPATION, excision; rooting out.

EXUDE, to discharge through pores or a membrane.

EXUDATION (v), the oozing of fluids through a membrane, etc. (s) material that has exuded or oozed from a vessel, etc.

FACET, a small, flat, articulating surface.

FECUNDATION, fertilization, impregnation.

FECUNDITY, the power or property of producing young.

FERMENTATION, the process by which certain substances are broken into their constituent parts by the influence of ferments. There are several kinds of fermentation, and each is thought to be due to the presence of a definite substance known as an enzyme. Some of the common forms of fermentation are: (1) alcohol or vinous fermentation, which is caused by a vegetable fermentation contained in yeast and which acts upon glucose, breaking it apart into alcohol and carbon-dioxide; (2) lactic acid fermentation due to lactic acid bacteria in which the sugar of milk—lactose—is broken down to lactic acid. Acetic acid fermentation, due to a peculiar vegetable ferment which acts upon alcohol, transforming it into acetic acid.

FIBRILS, small fibers.

FILAMENT, a thread; a slender thread-like process.

FOCUS, a point at which the rays of light refracted from a convex lens or reflected from a concave mirror tend to meet.

FORAMEN, an opening.

FOSSA, a depression; a groove.

GESTATION, pregnancy.

GLOBULINS, protein substances, somewhat similar to the albumins, but distinguished from them in that they are insoluble in water, saturated solutions of sodium chloride, and also in solutions of other salts in which albumins are soluble. Examples are: the serum globulin and fibrinogen of the blood.

GRANULAR, containing grains or granules.

GRANULATE, to form in granules or small masses.

GRANULATIONS, small granular-like fleshy bodies that form on the surface of suppurating wounds and ulcers.

HEMOLYSIS, disintegration or breaking up of red blood-corpuscles.

HEMOLYTIC, the property of, or a substance causing, hemolysis.

HEMORRHAGE, the escape of blood from its containing vessels.

HILUM or HILUS, a depression; a small aperture. Many of the glands and other organs of the animal body have such a depression through which the vessels and nerves pass to and from their interior.

HOMOGENOUS, of a like structure; consisting of the same elements.

HORMONES, chemical substances which stimulate certain of the organs of the body to activity; *e. g.*, the gastric secretion which stimulates the gastric glands to secrete the gastric juice.

HYDRATION, the act or process of moistening with water.

HYDROLYSIS, the breaking down of complex molecules into simpler ones with absorption of water.

HYDROTHERAPEUTICS, HYDROTHERAPY, the use of water for the cure of disease.

HYDROXIDE, a base or alkali.

HYPERTROPHY, excessive increase in the size of an organ or part.

IMPERMEABLE, not admitting of passage.

INFLUX, flowing in.

INGEST, taking in; *e. g.*, the introduction of food into the stomach.

INHIBITED, to check; to interfere.

INNERVATION, to supply with nervous force; the distribution of nerves to a part.

INOCULATE, the insertion of virus into a wound or abrasion in the skin for the purpose of communicating a disease.

INSULATE, to isolate; to separate.
INTERPOSE, to place between.
INTERSTICE, very narrow spaces between parts.
INVAGINATED, to enclose in a sheath.
INVESTURE, to clothe.

KATABOLISM, CATABOLISM, destructive metabolism. The breaking down of complex substances into more simple ones or their elements. Katabolism is the opposite of anabolism or building up.

LAMELLA, a thin plate; a scale, *e. g.*, the small plates of bone in the cochlea of the ear; the bony divisions of the Haversian system.
LATERAL, to the side.
LENS, a transparent substance, usually glass, bounded by two curved surfaces or by one curved and one plain surface. There are two general classes of lenses: (1) convex lenses, which are thicker at the center than at the edges; and (2) concave lenses, which are thinner at the center than at the edges. Convex lenses are termed converging lenses because they cause light to converge to a focus. Concave lenses are said to be diverging because they diverge rays of light. (*See* Refraction.)

MACERATE, to soften by steeping.
MAMMALIA, belonging to the class of mammals; *i. e.*, the class of animals that suckle their young.
MATRIX, a part of the body where new substance can be produced —*e. g.*, the uterus; the matrix of the nails.
MATTER, anything which occupies space and possesses weight; that of which the universe is composed.
MEDIAL, the middle.
MEDIAN, situated in or near the center; passing through or along the center.
MENISCUS (optics), a lens convex on one side and concave on the other. (Physics), the surface of a liquid column—as mercury—rendered convex or concave by capillarity.
MENSES, menstruation.
METABOLIC, pertaining to change.

METABOLISM, the changes that occur in food from the time it is absorbed until it is eliminated. This includes the breaking down and building up of body tissues, since they are constructed from the substances obtained from food.

MISCIBLE, capable of being mixed.

MOLECULAR MOTION, movement of the molecules composing matter. In gases the molecules are farther apart than they are in liquids, and therefore greater and more rapid motion goes on, and gases become diffused more rapidly than liquids. For the same reason there is more molecular motion in liquids than in solids, but even in solids there is movement of the molecules, as is shown by the fact that when two metals are placed one upon the other—*e. g.*, if gold is overlaid with lead, the presence of gold throughout the lead may in time be detected. But in solids the force of cohesion has its greatest intensity, and the molecules, although in constant motion, do not move from point to point within a body with freedom as they do in gases and liquids.

MOLECULE, the smallest particle of a compound that can exist.

MYDRIASIS, abnormal dilatation of the pupil.

MYOGEN, a form of albumin contained in muscle.

MYOSIN, a globulin contained in muscle (*see* Albumin *and* Globulin).

NEUROSIS, a nervous disease not associated with any discoverable lesion; *e. g.*, occupation neurosis, due to over-use or irritation of a part of the body in the performance of one's occupation.

NEUTRAL, neither acid nor basic.

NEUTRALIZE, to render neutral. When an acid and a base—alkali—are combined, the molecules of the acid minus their H atoms and the molecules of the base minus their OH atoms combine and form a salt; the H and OH unite to form water, H_2O. Thus: $NaOH + HCl = NaCl + H_2O$ NaOH is the chemical formula for sodium hydroxide, a corrosive, poisonous alkali. HCl for hydrochloric acid, a corrosive poisonous acid. NaCl, sodium chloride—common salt—is a neutral non-poisonous salt used with food.

NORMAL, according to the usual rule or type.

ORIFICE, an opening.

OSCILLATION, vibration; swinging backward and forward.

OSMOSIS: when two different liquids or solutions are separated by a porous partition or permeable membrane, they will pass through the dividing wall and intermingle. This diffusion of the two liquids is called osmosis.

OSMOTIC PRESSURE: if the liquids on either side of a membrane are of different specific gravities, *e. g.*, if one is water and the other salt solution, the liquid containing the greater amount of solid matter—*i. e.*, the salt solution—will exert a greater degree of pressure than the water, in consequence of which the water will pass through the membrane much more rapidly than the salt solution until the pressure on both sides the partition is equal. The pressure exerted in this way is spoken of as *osmotic pressure.*

OSSEOUS, bone-like.

OSSICLE, a small bone.

OXIDATION, the addition of oxygen to a substance. There are several forms of oxidation, *e. g.*, (1) the union of oxygen with elements as iron, zinc, copper, etc., with the production of an oxide of the element, *e. g.*, oxide of iron, which is commonly known as iron rust; oxide of zinc, etc.; (2) the decay of dead animal and vegetable matter is a form of oxidation, brought about by the action of bacteria; (3) the oxidation that takes place in the living animal body; (4) the oxidation of substances known as burning or combustion. Oxidation is always accompanied by the liberation of heat. If the oxygen unites very slowly with a substance, the amount of heat liberated is very small and hard to detect. If, however, the union with oxygen takes place rapidly, the heat generated is very perceptible, and if the union is sufficiently rapid the substance will burst into flame. It is then known as combustion. Unless a substance has a very strong affinity for oxygen, the use of a catalyzer is usually necessary in order to promote oxidation. Examples of common catalyzers operating in the forms of oxidation just mentioned are: heat, enzymes, bacteria. Except in the case of elements, the union of oxygen with a substance is usually followed by its disintegration (as has been already said), with the generation of heat and also the liberation of the energy that is stored up within it.

OXIDIZING AGENTS, substances containing a large amount of oxygen that is easily set free—*i. e.*, which is in loose combination.

PALPATION, making pressure on the surface of the body with the hand for the purpose of ascertaining the consistency of underlying parts.

PERONEAL, pertaining to the fibula.

PERISTALTIC, the worm-like movement by which the alimentary canal propels its contents.

PERMEABLE, that allows the passage of fluids.

PHENOMENON (plural phenomena), an observed result; an unusual appearance.

PHONATION, utterance of vocal sounds.

PIGMENT, coloring matter.

PIGMENT CELLS, cells which produce pigment.

PLANE, a flat surface.

PLEXUS, a network.

POLARIZED LIGHT: light is due to vibrations in the ether occurring in all planes transversely to the direction of the propagation of the wave. When the vibrations are made to take place all in one plane, the light is said to be *plane polarized*. The result is similar to regularly reflected light (*see* Reflection).

POLARIZER, an apparatus for polarizing light.

PROPAGATION, production.

PUNCTIFORM, in the form of a point.

PSYCHICAL, pertaining to the mind.

PSYCHOLOGIST, one versed in psychology—the science pertaining to the nature and functioning of the mind.

RADIATION, the diffusion of rays of light or heat.

REDUCE (surgery), to restore a part to its normal position, as a fractured bone; (chemistry), to take away oxygen from a substance.

REDUCING AGENTS, substances that having a strong affinity for oxygen extract it from other substances and thus reduce them.

REDUPLICATION, a doubling back.

REFLECT, to bend back. (Physics), the turning back of a ray of light, heat, or sound from a surface that it strikes, but does not penetrate.

REFLECTION—REGULAR and DIFFUSE: when a beam of light enters a darkened room through a small opening and strikes a mirror, a reflected stream of light will be seen traveling along a definite path; this is an example of regular reflection.

REFLECTION—REGULAR and DIFFUSE—*Continued*

If, however, the light strikes a rougher surface than the mirror,—for example, a sheet of white paper,—it will be reflected in a diffuse or scattered manner. This is diffuse reflection. It is caused by the inequalities of the reflecting surface. All rough surfaces, as well as inequalities in the atmosphere, such as dust or moisture, serve to diffuse light; were this not the case, it would be dark everywhere except in the direct path of light from some luminous body. It is because opaque objects reflect, or send back, the light which strikes them that they are visible.

REFRACTION, the deviation of light from its course. A straight stick placed at an angle, partly in water and partly in the air, looks like a bent stick. This is an example of the bending or refraction of light. The cause of refraction is that light travels with different velocity in different media; *e. g.*, the velocity of light in water is only ¾ of its velocity in air, therefore when a beam of light enters water its rate is

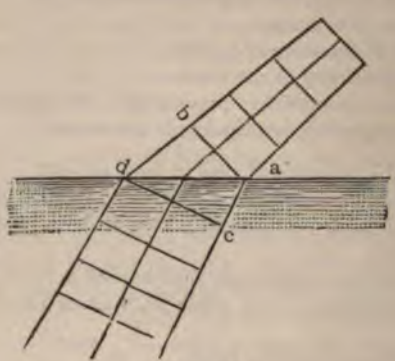

FIG. 1.

retarded; if the beam strike the water obliquely, all portions of the wave front will not enter the water at the same time; *e. g.*, in Fig. 1, let the short parallel lines represent the wave front of a beam of light entering obliquely from air into water, one part (a) reaches the water before (b), and, as it travels more slowly than before, it can go only as far as (c)

REFRACTION—*Continued*

while (b) is going to (d). Thus all the waves as they enter the water are given a new direction and the beam is bent. When a beam of light strikes the water vertically, it is not refracted because the whole front of a light wave strikes and enters the

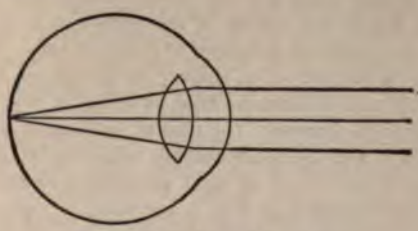

FIG. 2.—Normal eye.

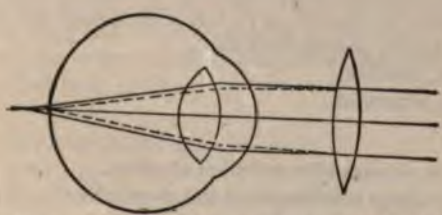

FIG. 3.—Hymertropic eye. The dotted line represents the refraction that the rays of light undergo in passing through the convex lens which brings them to a focus on the retina.

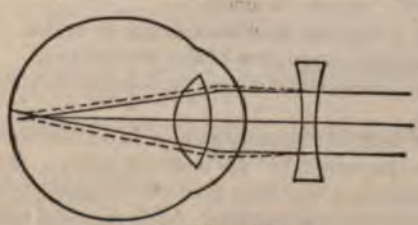

FIG. 4.—Myopic eye.

REFRACTION—*Continued*
water at the same time, consequently the whole wave front is retarded. Light is, of course, also refracted when it passes through glass and the refractive apparatus of the eye, and the degree and nature of the refraction is altered when the glass consists of a convex or concave lens. Thus, when the lens is convex—*i. e.*, thicker in the center than at the edges, the rays of light are bent as in Fig. 3, and the greater the degree of convexity the greater the degree of refraction of the rays and the more quickly will they be brought to a point or focus. Rays of light entering a concave lens (*see* Lens) will be bent as in Fig. 4 and their focussing thus prevented. For this reason concave glasses are worn in myopia (described in paragraph 965), as the rays of light, being slightly diverged before entering the eyes, are thus prevented focussing too quickly, *i. e.*, before they reach the retina.

REGURGITATION, passing backward.

RETICULAR, net-like.

RETIFORM, a network.

SALIVATION, an excessive secretion of saliva.

SALTS, substances resulting from the chemical union of a base and an acid. (*See* Neutralization.)

SAPONIFIED, converted into soap.

SCLEROSIS, hardness.

SCROTUM, part of the male organs of generation; it contains the testicles and their accessory organs.

SEGMENT, a part.

SEPTUM, a division; a wall.

SPECIFIC GRAVITY, the weight of a solution as compared with that of distilled water.

SPHINCTER, a ring-like muscle encircling an orifice.

STASIS, stoppage; stagnation of the blood-current.

STROMA, the tissue which forms the foundation substance of an organ.

SOUND, the form of vibratory motion in an elastic medium that can be perceived by the auditory nerves. Sound always originates in a vibrating body which starts trains of waves in the surrounding medium. Air is the usual medium for the transmission of sound waves, but any uninterrupted series

SOUND—*Continued*
of elastic bodies will answer the purpose, whether they be gases, liquids, or solids. Water is a particularly good transmitter: when the ear is under water the vibrations started by a steamer a mile away can be heard. Sound is perceived because the waves set in motion by the vibrating body enter the ear and set the drum membrane in motion as described in Chapter XXIV. The pitch of a sound depends on its vibrating frequency; the greater the frequency, the higher the pitch. The pitch of notes given forth by men is lower than those formed by women, since in men the larynx is larger and the vocal cords longer and thicker; wherefore they vibrate more slowly and produce a lower note. Some sounds have no definite pitch and are called *noises*. A noise generally consists of a mixture of unrelated sounds. A musical sound, on the other hand, is one which has a definite pitch and which is pleasing to the ear.

SUCTION, the act or process of sucking or drawing out.

SYNTHESIS, building; putting together.

TACTILE, pertaining to the sense of touch.

THERMIC, pertaining to heat.

THERMOGENIC, pertaining to the production of heat.

TOXIC, poisonous.

TRANSFUSION, the transfer of blood from one person to another; the introduction of such substance as saline solution into the blood-vessels.

TRANSLUCENT, slightly transparent.

TRUNCATED, deprived of limbs.

UNILATERAL, one-sided.

UNOSSIFIED, devoid of bone formation.

VASCULAR, containing a large number of blood-vessels.

VENOSITY, excess of venous blood.

VENTRAL, pertaining to the abdomen; the front surface of the body.

VENTRICLE, a small cavity.

VERMIFORM, worm-like.

VERTICAL, perpendicular.

VESICLE, a small bladder or sac; a blister.
VIBRATION, the act of moving rapidly to and fro.
VISCERA, the internal organs.

ZYMOGEN, a substance that gives rise to an enzyme.

QUESTIONS

For answers see Chapter I

Define biology, anatomy, physiology.

Upon what forces do the phenomena of life depend?

What is an element?

Name the elements composing the animal body.

How are the compounds composing the animal body classified?

What is meant by organic and inorganic substances?

Give some examples of nitrogenous compounds and mention the elements that generally enter into their composition.

Name the two classes of non-nitrogenous organic food-stuffs.

Name the principal carbohydrates found in plants and in animals, and state the elements that enter into their composition.

Of what elements is human fat composed?

What is a salt?

Mention the more important salts found in the human body.

What is the unit of the animal body from the chemist's and from the anatomist's standpoint?

Mention an important difference between the majority of cells of animal and of plant tissues.

Describe protoplasm.

Give an example of a one-celled animal.

How do cells multiply?

For answers see Chapter II

What are organs? Give examples

What is meant by a system?

Mention some examples of the dependence of organs and systems upon each other.

What is meant by the anatomical position?

Name the surfaces of the body and state their location.

Mention, and show on the skeleton, the main divisions of the body.

What is meant by medial?

What is meant by lateral?

What is the opposite of distal?

What is meant by the periphery?

What is understood by the terms "internal" and "external?"

What is meant by the terms "afferent," "centripetal," "efferent," "centrifugal"?

For answers see Chapter III

From what and how are the tissues of the body developed?

Name the substance that transmits characteristics from parents to their offspring.

State the meaning of the word "tissue" as it is used in anatomy.

How are the cells composing tissue held together?

How are the various tissues of the human body classified?

What is meant by organized matter?

Where are epithelial tissues found?

State some of the important functions of epithelial tissues.

Name the different tissues classified as connective tissues.

Why are they thus classified?

Where are connective tissues found?

What is areolar tissue and where is it found?

What is the most essential difference between white and yellow fibrous tissue?

Of what value is this difference?

Mention the different forms in which fibrous tissue is found in the body.

Describe ligaments and state their purpose.

What is the nature and what the purpose of tendons?

What are fasciæ and what is their function?

Where are the plantar and palmar fasciæ and what is their purpose?

What is the nature and the purpose of aponeuroses?

What is adipose tissue and in what parts of the body is it found?

Mention the uses of adipose tissue.

Describe lymphoid tissue and state where it is found.

What is cartilage like and where is it found?

Name the different varieties of cartilage?

What is the perichondrium?

How do the costal cartilages assist in respiration?

Where is cartilage found in the spinal column and what purpose does it serve there?

For answers see Chapter IV

What are the functions of the bones?

Of what does bone consist?

How does the relative proportion of organic and inorganic matter in bone vary during life?

How does this difference in composition influence the strength of bone and the nature of fractures?

What is the cause of rickets?

How are the bones of the body classified?

What is the more porous portion of bone called?

Mention the names of some of the more important markings of bones and state their purpose.

What constitutes an *Haversian System?*

What is the purpose of the Haversian canals?

Where are the medullary canals and what purposes do they serve?

State the nature and purpose of marrow.

What is the periosteum?

Why is injury to the periosteum likely to result in necrosis of the bone?

Describe the process that occurs in the repair of bone after fracture.

How many bones are there in the human skeleton?

Name the bones of the skull.

What bones enter into the formation of the base of the skull?

Where are the mastoid bones?

What is there in the structure of these bones that renders mastoiditis a particularly dangerous disease?

What and where are the frontal sinuses?

Where is the ethmoid bone?

What are the fontanelles?

Where are the turbinated bones?

Where and what are the antra of Highmore?

How many vertebræ are there in the spinal column?

How are the vertebræ classified?

Of what use are the curves of the spinal column and the pads of cartilage between the vertebræ?

Mention the names given certain abnormal curves of the spinal column.

Give the names of the two uppermost vertebræ.

What peculiarity is there in the arrangement of these two vertebræ that makes fracture of this part of the spinal column (broken neck) particularly likely to be fatal?

Describe the sternum and state its position.

How many ribs are there?

How are they classed and why?

What is meant by the shoulder girdle?

What is the technical name for the collar bone?

Where is it situated?

Where is the glenoid cavity?

Describe the humerus.

Name the bones of the forearm.

What and where is the olecranon process?

How are the bones of the wrist classed?

What name is given to those of the fingers?

Describe the phalanges.

Name the bones of the pelvis and state their location.

What is meant by the false and the true pelvis.

What is the prominent line between these two parts of the pelvis called?

What is the upper ridge of the ilium called?

Name the bones of the lower extremity and state their relative position.

Describe the femur.

Describe the patella.

Where are the inner and the outer malleolus?

For answers see Chapter V

How are joints classified with respect to the amount of movement that they are capable of?

Give examples of immovable and slightly movable joints.

Describe the articulations of the spinal column.

Mention the principal features of the freely movable joints.

What are bursæ?

What is synovitis?

What is bursitis?

Name the different kinds of movements of which joints are capable.

Describe abduction and adduction.

Describe circumduction.

Describe flexion and extension.

Describe rotation.

What is meant by gliding movements?

Name the ball and socket joints and state the movements they are capable of.

Give examples of hinge joints and state the movements that they are capable of.

Give examples of condyloid joints.

Give examples of pivot joints.

Give examples of gliding joints.

Give examples of saddle joints.

Describe the gums.

Name the different parts of a tooth.

Describe the structure of the teeth.

Name the temporary teeth and state the ages at which they appear.

Name the permanent teeth.

How are the teeth developed?

For answers see Chapter VI

Mention some of the constituents of muscle tissue.

Name the different kinds of muscle tissue and give reasons for the names.

Of what nature is the plasma of muscle cells?

Describe the structure of plain muscle tissue.

Describe the structure of striated muscle tissue.

Mention some points of difference between cardiac muscle tissue and plain and striated muscle tissue.

What are the special characteristics of muscle tissue?

What is meant by irritability?

By stimuli?

By contractibility and extensibility?

By elasticity?

Mention some chemical changes that occur in muscle as the result of contraction.

Of what importance are these chemical changes to the body?

What is the cause of muscle fatigue?

When and how will the muscle recover from fatigue?

What is meant by tetanus of muscle?

What is meant by muscle tone?

How is it produced?

What is the origin of the nerve impulses that give rise to muscle tone?

Give examples showing that mental activity affects muscle tone.

What is the result of cold on muscle tone? Give an example.

Mention some differences between the contraction of voluntary and involuntary muscle tissue.

What is meant by the skeletal muscles?

What is meant by the origin and insertion of muscles?

How are muscles attached to the bones?

Of what value to the movements of the body is the tension that, normally, the muscles are under?

Name the muscles that control the movements of the eyeball.

Of what special use are the muscles which form the cheeks and have their insertions in the lips or jaws?

Why is the tongue likely to fall back over the trachea after the taking of a general anesthetic?

Name some of the principal muscles of the back. Of the chest.

Where is the diaphragm? State its functions.

Mention the actions of the abdominal muscles.

What is meant by the inguinal canal?

What is a hernia?

Name some of the more common forms of hernia of the intestines and state where they occur.

Name the large muscle covering the prominent part of the shoulder and state its action.

Name the large muscles of the upper part of the arm.

State how the abductors and adductors, flexors and extensors, pronators and supinators of the forearms and legs are placed with relation to each other.

What are the annular ligaments?

What may be the result of cutting any of the tendons that hold muscles to the fingers?

For answers see Chapter VII

Name some of the special characteristics of nerve tissue.

Name the principal parts of the nervous system.

Which of these parts constitutes the cerebro-spinal portion of the nervous system and which the sympathetic portion?

Mention a point of similarity between the structure of nerve tissue and other tissues.

Name the different parts of a nerve-cell.

Describe the dendrites.

What is the axis-cylinder of a nerve-cell?

What are collaterals?

Mention the different kinds of nerve-fibers.

What is the neurilemma?

What are the nodes of Ranvier?

What is the difference between a medullated and a non-medullated nerve-fiber?

What is thought to be the function of the medullary sheath?

What is the function of the nerve-fibers?

What are the nerve-endings?

How are nerve-fibers classified with regard to the way in which they are stimulated and the result of their stimulation?

Give reasons for the names used?

How do sensory nerve-endings and nerve-centers react to different kinds of stimuli?

What may be the result of afferent impulses upon different sets of nerve-centers?

What are nerve-centers?

What is the neuroglia?

What is the difference between the gray matter and the white matter of the nervous system?

How are the gray matter and the white matter distributed in the body?

What are ganglia?

What are plexuses?

Of what value are plexuses?

What is meant by the respiratory center?

What is meant by vaso-motor centers?

Describe the arrangement in the nerve-centers by means of which impulses can pass from afferent to efferent nerve-fibers.

Mention some of the theories that have existed regarding the nature of nerve impulses.

What are the functions of the cell bodies?

What is meant by reflex action?

Mention some activities that are at first volitional but later become reflex.

What is meant by the reflex arc?

What is meant by the modification of impulses?

What is meant by the inhibition of reflexes? Give an example.

What is meant by diffusion of impulses? Give an example.

What is meant by automatism?

What is said of the origin of voluntary impulses?

Upon what does the repair of injured nerve-fibers depend?

What is thought to be the effect of excessive fatigue upon the cell bodies?

For answers see Chapter VIII

What is the average weight of the brain?

What are the ventricles of the brain?

Name the ventricles.

Name the main divisions of the brain.

Where is the cerebrum?

What is the relative position of the gray matter and the white matter in the cerebrum?

Of what is the gray matter of the cerebrum composed?

What is meant by the fissures of the cerebrum?

What are the gyres?

State the functions of the cerebrum.

What is meant by the motor area of the cerebrum?

How have the portions of the cerebrum that control movements in different parts of the body been localized?

How is it that injury to parts of the brain on the right side will result in loss of function in some part of the left side of the body?

What is meant by the sense areas?

What is aphasia?

What is the difference between sensory and motor aphasia?

What and where are the association areas?

How do the association areas vary in different individuals?

Mention two things that are necessary for the development of any special talent.

Where is the mesencephalon?

Where is the cerebellum?

What are the functions of the cerebellum?

Where is the pons Varolii?

Where is the medulla oblongata?

What is meant by the decussation of the pyramids?

Why is injury to the medulla oblongata likely to result in death?

Name the membranes covering the brain and state their relative position.

Describe the dura mater.

Describe the pia mater.

Describe the arachnoid.

What is the cerebro-spinal fluid and what is its purpose.

For answers see Chapter IX

Where and what is the spinal cord?

Name the membranes surrounding the spinal cord.

Describe the structure of the cord.

Mention the functions of the spinal cord.

How many cranial nerves are there?

Why are these nerves called the cranial nerves?

With what sense is the olfactory nerve concerned?

With what sense is the optic nerve connected?

What is the name of the nerve concerned with hearing?

What function is dependent upon some of the fibers of this nerve?

To what organs do fibers of the vagus nerve extend?

How many spinal nerves are there?

How do they get through the vertebral column?

Why are the spinal nerves said to be mixed nerves?

What is meant by the spinal ganglia?

What is meant by the rami communicantes?

What constitutes the sympathetic portion of the nervous system?

What and where are the lateral ganglia?

Describe the distribution of the sympathetic nerves.

Name some of the important plexuses of the sympathetic system.

What is the function of the sympathetic portion of the nervous system?

Mention some instances in which the action of the nerves of the sympathetic and the cerebro-spinal portions of the nervous system are antagonistic to each other.

Describe the action of the vaso-constrictor nerves.

Describe the action of the vaso-dilator nerves.

Where is the great sciatic nerve?

For answers see Chapter X

Of what nature are the membranes of the body?

How are the membranes classified?

What is the chief function of the membranes?

How do the membranes protect the body?

Where are the serous membranes found?

Give the names of some important serous membranes.

Where are the synovial membranes found?

How are synovial membranes classified?

What are bursæ and where are they found?

What is bursitis?

What is synovitis?

Where are the mucous membranes?

Mention some differences in the structure of mucous membranes in different organs, and state why these differences are of importance.

In what ways do mucous membranes differ from serous membranes?

Why does the condition of the tongue give a clue to conditions in the stomach and intestine?

Mention an important point of difference between the secretion of a mucous membrane and that of a serous membrane, and state why this difference is necessary.

For answers see Chapter XI

Mention the main divisions of the vascular system.

What organs constitute the blood-vascular system?

Name the parts constituting the lymph-vascular system.

Mention the principal functions of the blood.

What characteristics of the blood-vessels and the circulation enable the blood to perform its function?

How much blood is there in the human body?

Mention the special characteristics of the blood.

To what is the color of the blood due and why is its color variable?

Of what is the blood composed?

What is meant by blood plasma?

What is blood serum?

What do the solid substances in the blood represent?

What are the red corpuscles called and why?

Describe the erythrocytes.

What is their purpose?

What constituent of the erythrocytes enables them to perform their function?

What is hemoglobin?

What is oxyhemoglobin?

What is the normal per cent. of hemoglobin in the body?

What is meant by 100 per cent.?

What is meant by anemia?

Why are foods containing iron given in the treatment of anemia?

Why is anemia likely to complicate bacterial diseases?

Why is anemia a serious condition?

About how many erythrocytes are there in a cubic millimeter of blood?

Mention some causes for a reduction in the number of red cells.

Can an individual be anemic if he has the normal number of red cells in his blood?

In what part of the body are the red cells formed?

Mention some of the names by which the white corpuscles are distinguished.

Describe the white corpuscles.

Where are they found?

What is the comparative number of white to red cells?

Where are the white corpuscles thought to be formed?

Mention some important points of difference between the white and the red cells.

State the function of the white corpuscles.

What are the phagocytes?

Describe the process that occurs in inflammation.

What are opsonins?

What are blood-plates?

What is their function?

What is fibrinogen?

For what is it essential?

What is meant by antibodies?

What is meant by immunity?

What are antitoxins?

Describe the process that occurs in the clotting of blood.

To what is clotting due?

Of what advantage to the body is the clotting of blood?

Mention conditions that promote, and conditions that retard, the clotting of blood.

Why does the blood not often clot within the living blood-vessels?

What conditions sometimes cause it to clot in the vessels during life?

What is a clot thus formed called?

What name is given to the clot if it moves from the place where it formed?

Why is a thrombus dangerous?

How is the blood regenerated after hemorrhage?

Of what benefit are saline infusions after hemorrhage?

What is physiological salt solution and why is it used for intravenous infusions?

Why is it exceedingly important to have the right amount of salt in saline solutions that are used for this purpose?

What is meant by blood transfusion?

Why can not the blood of one of the lower animals be used for transfusion into man?

What is meant by hemolysis?

What is meant by laked blood?

What is meant by defibrinated blood?

From what is the lymph derived?

What are the essential differences between lymph and blood?

Where is the lymph found?

What are its functions?

For answers see Chapter XII

Name the organs composing the blood-vascular system.

State the functions of these organs.

Where will you put an ice-cap that is to be placed over the heart?

How is the heart held in place?

Of what are the walls composed?

What is the membrane covering the heart called?

What is the name of the membrane lining the heart?

How is the pericardium arranged?

What is its purpose?

How many chambers are there in the heart?

Which ones communicate with each other?

How many orifices has each chamber and into what do they open?

Which of the orifices have valves and what are the names of the valves?

Name the blood-vessels opening into the heart and state their purpose.

Describe the structure of the bicuspid and tricuspid valves.

What is the purpose of these valves?

What keeps them from floating into the auricles?

Why will endocarditis interfere with the closing of valves? (See Endocarditis in *Practical Nursing* or other text-book.)

What is likely to be the result of such interference?

What arteries supply the walls of the heart with blood?

From what part of the nervous system are the nerves that supply the walls of the heart derived?

What does the word "artery" mean and why were the arteries so called?

Describe the structure of the arteries.

What is arteriosclerosis?

In what ways do the veins differ from the arteries?

Describe the capillaries.

How are the capillaries distributed through the body?

What constitutes the lymphatic system?

What is meant by the lymph spaces?

What are the nature and the purpose of the lymph vessels?

Name and state the location of the two largest lymph vessels.

Describe the lymph nodes or glands.

What is their purpose?

Where are they situated?

Name some important ones.

Why are abnormal conditions of the tonsils a source of danger?

For answers see Chapter XIII

What are the three main divisions of the blood-vascular system?

State the function of each of these systems.

Mention some of the main features in the method of the distribution of the blood-vessels.

What is meant by anastomosis?

Of what use are the anatomoses of blood-vessels?

What names are given to various parts of the aorta?

With what part of the heart does the aorta connect?

Name the large blood-vessels that branch off from the thoracic aorta and state the organs that they supply with blood.

Mention the branches of the abdominal aorta.

How does the brain get its blood supply?

How does the blood return from the brain to the heart?

Trace the course of the blood from the heart to the fingers of the right hand and back to the left side of the heart.

On what artery, and where, would you make indirect pressure to stop hemorrhage from a wound in the arm?

What difference is there in the number of blood-vessels through which the blood must flow to the right and to the left hand?

Name the principal vessels through which the blood flows from the heart to the toes and back to the left side of the heart.

How will the blood get from the right side of the heart to the right hand?

What artery will you compress, and where, to arrest hemorrhage from a wound in the thigh?

Trace the blood from the right auricle to the lungs and back?

Through what arteries does the blood intended for the nourishment of the lungs travel?

Of what does the portal system consist?

What blood passes through it?

Why is it necessary that the blood from the intestines should go to the liver before entering the general circulation?

For answers see Chapter XIV

Describe the nature of the heart action.

What is the meaning of the heart's systole and diastole and the cardiac cycle?

State the time required for the systole and diastole

of the auricles and ventricles when the pulse beat is 72 per second.

How much complete rest per minute does the heart get when it is working at the rate of 72 cycles per minute?

Why should the recumbent position be maintained whenever possible when the pulse rate is much increased?

What is meant by heart murmurs?

What causes the heart to beat?

What influence have the vagi nerves and what those of the sympathetic system upon the heart?

What are the main factors in maintaining arterial circulation?

What are the principal factors in maintaining venous circulation?

What is meant by the suction action of the heart?

How long does it take blood to go from the heart, through the system and back to the heart?

In what way does the rate of the blood-flow differ in the different vessels and why does it differ?

What are the main causes of differences in the quantity of blood in different parts of the body?

Why is it hard to study after eating a large meal?

Why is it not well to take a bath immediately after dinner?

What is meant by blood-pressure?

What causes differences in the degree of pressure in different vessels?

How can the degree of blood-pressure be ascertained?

What is the cause of the pulse?

Where can the pulse be most easily counted?

What can you tell about the heart action and the condition of the blood-vessels by feeling the pulse?

What is meant by a dicrotic pulse?

What is meant by an irregular pulse?

Mention the principal forces that control the flow of lymph.

What is meant by edema?

Mention some causes of edema.

For answers see Chapter XV

Mention the purposes of respiration.

What is meant by internal and what by external respiration?

Name the organs concerned in respiration.

What are the functions of the nose?

Name the divisions of the nose.

Describe the structure of the nose.

State some reasons why mouth breathing is harmful?

Why does a cold in the head interfere with the sense of smell?

Where are the frontal sinuses and the antra of Highmore and why do they frequently become infected?

Describe the pharynx.

How many openings are there into the pharynx?

Why will lack of care of the mouth easily result in infection of the inner ear?

Where and what is the larynx?

Name some of the important cartilages of the larynx and state their purpose.

What and where is the epiglottis?

What is its function?

What are the vocal cords?

What and where is the glottis?

What and where is the trachea?

Describe the structure of the trachea.

What is the purpose of its ciliated epithelium?

What and where are the bronchi?

What are the branches of the bronchi called?

What are the alveoli?

What is their purpose?

Where are the lungs?

Describe them.

In what way does the right lung differ from the left?

What vessels hold the blood flowing from the heart to the lungs?

How are the blood-vessels distributed in the lungs?

Name the membrane that invests the lungs and describe its arrangement.

What is its function?

What name is given to inflammatory conditions of this membrane?

What constitutes external respiration?

Describe the mechanism of inspiration.

Name the principal muscles concerned in inspiration.

Describe the mechanism of expiration.

Why are the respiratory movements only very slightly under the control of the will?

What are the causes of respiration?

In what ways do certain of the sensory nerves influence respiration?

What is the condition of the lungs in the fetus? Why?

What causes the first respiratory movement at birth?

What physical forces are involved in the interchange of gases that takes place in the lungs?

What interchange of gases takes place in the tissues?

From what is the carbon dioxid that is present in the tissues derived?

State the changes that take place in the blood as the result of respiration.

What is the normal rate of respiration?

Why is the rate of the respiration increased in fever?

What is meant by tidal air? Complemental air? Reserve air? Residual air?

What is the average amount of air exchanged during quiet respiration?

What is meant by the vital capacity of the lungs?

What are the forces causing movement of air in the lungs?

What is the value of this movement?

State the usual composition of air as it is inspired.

State the composition of that expired.

What, therefore, are the differences between air as it is inspired and expired?

What bad effects may result from being in a badly ventilated room?

To what are these effects due?

Why is oxygen necessary for life?

Upon what are estimates of the amount of air space required per capita based?

In reckoning the necessary size of rooms that are to be inhabited by many people, what conditions must be considered?

What is meant by dyspnea?

What is the cause of dyspnea?

What is the nature of Cheyne-Stokes respiration?

What is the nature of the respiration in edema of the lungs?

Why is edema of the lungs a dangerous condition?

What is asphyxia?

Why are convulsions a common accompaniment of asphyxia?

Mention common causes of hiccough.

What is meant by the resonance cavities and why are they so called?

How is the action of speaking accomplished?

For answers see Chapter XVI

What is a gland?

Mention some general characteristics in the structure of glands.

How are glands classified?

What is meant by a secretion?

What by an excretion?

Mention some excretions that are used by the body.

How are secretions classified?

What is meant by an internal secretion?

Name some of the more important internal secretions.

Name the ductless glands.

What is the purpose of the secretion of the suprarenal capsules?

Where is the thyroid gland?

What is the purpose of the secretion of the thyroid gland?

What is the purpose of the secretion of the pituitary body?

What is the purpose of the thymus gland?

Of what use are the parathyroid glands? Where are they?

What is thought to be the purpose of the internal secretion of the ovaries?

Where is the spleen situated?

How large is it?

Mention some of the important features of its structure.

State some of the purposes that the spleen is thought to serve and give the reasons for the supposition.

For answers see Chapter XVII

Name the organs that are concerned with the digestion of food.

Describe the mouth.

Where and what are the hard and soft palates and the uvula?

What are the palatine arches?

Where and what are the tonsils?

What is the function of the tonsils? (See page 257.)

Under what conditions do the tonsils become a source of danger to the body and why? (See page 257.)

Perform the action of swallowing and decide how the soft parts at the back of the throat prevent food entering the naso-pharynx.

What part does the tongue take in digestion?

What is the nature of the various papillæ of the tongue?

Name, and give the location of, the salivary glands

Where is the esophagus?

What is it like?

Name the regions of the abdomen.

On what part of the abdomen will you place an application that is to be put over the stomach?

Where would you put one that was to be over the liver?

Where would you place one to be over the right kidney?

How would you know if the bladder was distended?

What is the peritoneum?

What and where is the omentum?

What and where is the mesentery?

Mention the important purposes of the peritoneum.

What are the names of the different parts of the stomach?

Name the organs that come in contact with the stomach.

What is the size of the stomach?

Name the different kinds of tissue that enter into the structure of the walls of the stomach and describe their arrangement.

In what way does this arrangement help the functioning of the stomach?

Where are the glands which secrete the gastric juice and the hydrochloric acid situated?

Name the openings of the stomach and state where they are situated.

Where is the small intestine situated?

What is its purpose?

State the names and location of the different parts of the small intestine.

How long is the small intestine?

Describe the walls of the small intestine.

What are the valvulæ conniventes?

Describe the villi of the small intestine.

What is their purpose?

Name the glands that are situated in the walls of the small intestine and state their purposes.

State the length and position of the large intestine.

What names are applied to different parts of it?

How do its walls compare with those of the small intestine?

What is the purpose of the large intestine?

How long is the rectum?

How far is it possible to insert a rectal tube without having it bend upon itself?

By means of bismuth injections it has been found that fluid is carried much higher into the intestine than this, what feature in the action of the intestine makes this possible?

Where is the vermiform appendix?

Where and what is the cecum?

What guards the opening between the large and the small intestine?

What is the purpose of this sphincter and valve?

What and where is the pancreas?

What is its purpose?

How does the pancreatic digestive juice enter the intestine?

What is the purpose of the internal secretion of the pancreas?

What and where is the liver?

Describe the liver.

Name the large veins that enter and leave the liver and state their origin.

In what way does the blood coming to the liver by the portal vein differ from that flowing through the hepatic artery?

What is the purpose of the liver?
Name the ducts of the liver.
What and where is the gall-bladder?
Through what duct does the bile enter the intestine?
Into what part of the intestine does this duct open?

For answers see Chapter XVIII

How are foods classified?

What classes of food-stuffs constitute the organic foods and what the inorganic?

Give examples of the protein or nitrogenous food-stuffs and state in what foods they are found.

What elements enter into the composition of proteins?

Of what elements are fats and carbohydrates composed?

Name the different kinds of carbohydrates.

Why are these foods called carbohydrates?

How are sugars classified?

What is the main difference between the composition of these two classes of sugars?

Of what are fats composed?

Name some substances in which fat is soluble.

What is meant by saponification?

What substances will saponify fat?

What is lecithin and where is it found?

What is cholesterin?

Mention the purposes of the organic foods in the body.

What purpose do the proteins serve in the body that carbohydrates and fats do not?

What are some of the important uses of inorganic food substances in the body?

Give a definition of digestion.

Why is digestion of food necessa y?

Under what two heads are the digestive processes classified?

What constitutes the mechanical processes of digestion?

What is the nature of chemical digestion?

How can the same changes that occur in food as the result of digestion be accomplished outside the body?

How is it possible for the chemical changes that occur in digestion to take place at body temperature?

Of what do the digestive juices consist?

Where is the saliva secreted?

Mention factors that influence its secretion.

Name the enzymes it contains.

Where is the gastric juice secreted?

Name the enzymes it contains.

Mention factors that influence its secretion.

What are the purposes of the hydrochloric acid?

From what is the hydrochloric acid made?

What is a zymogen?

Where is the pancreatic juice secreted and what factors influence its secretion?

Name its enzymes.

Where is the succus entericus secreted?

Name its enzymes.

What is the action of the enterokinase?

Name the various stages through which starch passes and the enzymes that cause the changes.

Through what changes do the proteins pass and what enzymes produce the changes?

Where does the digestion of proteins take place?

What foods are affected while in the stomach?

What changes take place in sugars during digestion and what enzymes cause the changes?

In what part of the digestive apparatus is the food while it is undergoing pancreatic digestion?

Where are fats digested and what substances are responsible for their digestion?

What is the bile? Where is it secreted?

To what are the changes that occur in food in the large intestine due?

Of what is intestinal putrefaction the result?

Why is this to be avoided?

How long does it take food to pass through the intestines?

Where does absorption take place?

Name the various substances into which the different foods are changed before they are absorbed.

Which of these substances are found in the blood?

What is supposed to be the reason that the others are not found?

What is chyme?

What is chyle?

For answers see Chapter XIX

When does the food first begin to be of use to the body?

What is meant by metabolism?

What is the nature of the metabolic changes that occur in the food products?

Mention factors that influence metabolism.

How are salts formed in the body?

What is the result of metabolism?

What is meant by oxidation?

State the various changes through which glucose passes after it has been absorbed.

What are the final products of the metabolism of glucose?

What will be the result if the metabolism of glucose is interfered with, as it is in diabetes?

What happens to fats after they have been absorbed?

What is the function of fats?

Mention some causes of obesity.

What is meant by nitrogen equilibrium?

What is the special function of proteins in the body?

State some of the changes caused in proteins as the result of metabolism.

What is the heat value of proteins, carbohydrates, and fats?

Upon what does the amount of food required depend?

How much food does an averaged-sized man at light labor require per day?

How does the amount of food required by a woman compare with a man's requirement?

What proportion of a man's ration does a child of six require?

Why do children need more food in proportion to their size than adults?

Mention some of the bad effects likely to result from eating too much food.

How is heat produced in the body?

Where is it produced?

If heat is produced to a greater extent in some parts of the body than others, how is it that all the interior of the body has about the same temperature?

Through what channels is excess heat eliminated from the body?

How is the greatest amount of heat eliminated?

How is the formation and loss of heat in the body regulated?

Mention some external conditions that influence the loss of heat.

Why does heat prostration occur more frequently on hot days when the humidity is high than when there is not much moisture in the air?

Why does shivering increase heat formation and prevent loss of heat?

How and why do cold baths affect the temperature?

Mention some of the supposed causes of fever.

Why is the respiration increased in fever?

In what way is fever thought to be of use to the body?

For answers see Chapter XX

Name the excretory organs.

What waste matter is eliminated through the urinary organs?

What through the respiratory organs?

What through the skin?

Name the excretion eliminated by the liver.

From what is the matter eliminated through the excretory organs derived?

What organs constitute the urinary system?

Where are the kidneys situated?

How are they retained in place?

What is a common cause of loosening of the kidneys from their position and what is the condition called?

Of what shape are the kidneys?

What is meant by the hilum of the kidney?

Name the different parts of the kidneys and the structures forming each part.

What are the uriniferous tubules?

What are the Malpighian capsules?

What are the Malpighian bodies?

What is a glomerulus?

What are the calyces of the kidneys?

What and where is the pelvis of a kidney?

Of what do the pyramids consist?

What arteries supply the kidneys with blood?

What is meant by the capsule of a kidney?

What is the nature of the process by which urine is excreted?

Where and what are the ureters?

Where is the urinary bladder situated?

What is meant by retention of urine?

What are the usual causes of retention of urine?

What is meant by retention with overflow?

What symptoms should lead you to think that the passage of urine involuntarily was the result of retention?

Mention some bad results that might follow retention of urine after an abdominal operation?

How much urine does an adult pass, normally, during the twenty-four hours?

How much do children of about two, five, and nine years of age pass?

Mention some causes likely to diminish the secretion of urine.

Mention causes that are likely to increase it.

Mention some causes for changes in the color of urine and state the nature of the change in each case.

What is the normal reaction of urine and to what is this reaction due?

State the composition of urine.

What is urea?

State the average amount of urea passed by an adult in twenty-four hours and some causes for changes in the amount.

From what is uric acid derived?

In what form is it usually found in the urine?

From what are the salts that are found in urine derived?

Under what circumstances is albumin likely to be found in the urine?

Mention some causes for the appearance of glucose in the urine.

From what is aceton derived and when is it likely to be found in the urine?

What is the source of indican and what does its presence in the urine indicate?

What are casts?

What may be the origin of urinary calculi?

What does the presence of pus in the urine indicate?

Of mucus?

Of blood?

What is the difference between retention and suppression of urine?

What will be the result if the kidneys fail to secrete the urine and why will there be such a result?

For answers see Chapter XXI

Mention the functions of the skin.

What are the two main parts of the skin?

Mention some of the main features in the structure of the epidermis.

Why can imprints of the hands be used for identification purposes?

How can blisters be caused and why?

Describe the principal features in the structure of the derma.

Name the different kinds of nerves that have their peripheral terminations in the skin.

Name the glands of the skin and state their purposes.

How much perspiration is secreted in twenty-four hours at ordinary temperatures?

What is meant by insensible perspiration? Why is it so called?

Mention causes for increase in the degree of perspiration.

Mention common causes for decrease in the amount of perspiration excreted.

How is the activity of the sweat glands controlled? Give examples.

Of what is sweat composed?

What is the principal value of the excretion of sweat?

Where are the ceruminous glands situated?

What is the secretion of the ceruminous glands called and what is its purpose?

Where are the sebaceous glands found?

What is the secretion of the sebaceous glands called and what is its purpose?

Discuss the value of the skin as an absorbing organ.

How must inunctions be given if the substance used for the purpose is to be absorbed, and what must be the nature of the substance?

What are meant by the appendages of the skin?
Name the different parts of a hair.
Upon what does the growth of hair depend?
What causes the appearance known as *goose-flesh?*
Name the different parts of a nail.
How does the growth of the nails take place?

For answers see Chapter XXII

What causes sensation?
What are the essential parts of a sense organ?
Where are sensations perceived?
How are sensations classified?
Give reasons for the classification.
How is the sensation of pain perceived?
What gives rise to the sense of hunger?
What causes the sense of thirst?
What is meant by muscular sense? Give examples.
What causes the sense of fatigue?
How are the sensations produced that cause vomiting, micturition, coughing, and the like?
What is meant by the pressure or tactile sense?
How are the nerve endings connected with this sense stimulated?
In what parts of the body are pressure nerve-endings most abundant?
What is meant by the temperature sense?
What name is given to the nerve endings connected with this sense, where are they situated, and how are they stimulated?
Mention some of the results of stimulation of the cold spots.
Mention conditions necessary for the stimulation of the olfactory nerve-endings.

Where are the nerve endings of the nerves connected with the sense of taste contained and what are they called?

How are they stimulated?

For answers see Chapter XXIII

What constitute the essential parts of the organ of vision?

What are meant by the appendages of the eye?

What are the eyebrows?

Describe the eyelids.

What are the Meibomian glands and where are they situated?

What constitutes the lachrymal apparatus of the eye?

Where is the lachrymal gland situated?

Where is the lachrymal sac? Into what does it open?

Where is the nasal duct?

What is the purpose of the lachrymal gland?

What is the purpose of the tears?

How do they reach, and how are they removed from, the surface of the eye?

Where and what is the conjunctiva?

Under what two headings are the muscles concerned with the eye considered?

Which of the eye muscles are classed as the intrinsic muscles?

Name the muscles classed as the extrinsic muscles and state their purpose.

Describe the orbits.

Why are people's eyes likely to look sunken after illness?

Name the coats of the eye.

Describe and locate the sclera.

With what is it continuous?

Describe the cornea.

Point out and describe the choroid.

Where and what is the ciliary zone?

Describe the position and nature of the iris.

Where and what is the pupil?

Describe the location and the nature of the retina.

What and where is the fovea centralis?

What and where is the blind spot?

What is meant by the humors of the eye?

What and where is the crystalline lens?

Describe the manner in which the crystalline lens is held in position.

Why do we see objects?

What is meant by the refractive apparatus of the eye and what parts of the eye compose it?

Describe the action of the refractive apparatus.

What is meant by hypermetropia?

What is meant by myopia?

What is meant by astigmatism?

What is the function of the iris?

Describe the manner in which its function is performed.

What is the function of the retina?

How do we judge of the size of objects?

How do we know that objects are moving?

How do we estimate the solidity of objects?

In what ways do the eyes resemble the photographer's camera?

To what is the color of light due?

Why is sunlight of a white hue if it contains so many colors?

To what is the color of objects due?

What makes objects look white?

What makes them look black?

Why are objects not always the same color under artificial lights as by daylight?

Mention one theory regarding the reason why color can be perceived.

Mention one theory regarding the reason for color blindness.

For answers see Chapter XXIV

Mention the main divisions of the ear.

Of what does the external ear consist?

Describe the auricle.

What is the purpose of the ceruminous glands?

Describe the auditory canal.

How are the external and middle portions of the ear separated?

Name the bones found in the middle ear and state their relative location.

How many, and what, openings are there in the middle ear and with what do they communicate?

Why can inflammation in the middle ear give rise to mastoiditis?

What is the function of the Eustachian tube?

Why is obstruction of this tube a serious matter?

Name the different parts of the inner ear and state their relative position.

What is the membrane lining the inner ear called?

Describe the structure of the cochlea.

What is its purpose?

What is the organ of Corti?

Describe the structure of the vestibule.

Describe the structure of the semicircular canals.

What is their purpose?

What will be the result of disease of this part of the ear?

With what part of the brain do the nerve-fibers from this part of the ear communicate?

Describe the process that gives rise to hearing.

For answers see Chapter XXV

Under what two headings are the female organs of generation divided?

Name the internal organs of generation.

Where are the ovaries?

Describe their structure.

What are the Graffian follicles?

What is their purpose?

About how many follicles are there usually in an ovary?

What is meant by ovulation?

What is the corpus luteum?

What and where are the Fallopian tubes?

What are the fimbriæ of the tubes?

What is their purpose?

What is the purpose of the tubes?

What name is given to the condition that arises when a fecundated ovum remains in a Fallopian tube?

What and where is the uterus?

How large is the uterus?

Name the different parts of the uterus.

Describe the structure of the uterine walls.

How is the uterus held in position?

What and where are the broad ligaments?

What and where is the vagina?

Describe the structure of the vagina.

Name the external organs of generation.

What and where is the mons Veneris? The labia majora? The labia minora? The clitoris? The hymen? The perineum?

What is meant by puberty?

What is meant by the menopause or climacteric?

What changes occur in the uterus in connection with menstruation?

In what way are the ovaries thought to influence menstruation?

Describe the ova.

Describe the spermatozoa.

What happens to the ova after they are discharged from the ovaries?

What is meant by the decidua?

What is the decidua vera? The decidua serotina? The decidua reflexa?

Describe the first stages in the development of an ovum after fecundation.

What is the amnion?

What are its purposes?

Describe the placenta and state its purpose.

Describe the umbilical cord and state its purpose.

What is the condition of the lungs during intra-uterine life?

How does the fetus get oxygen and part with carbon dioxide and other waste matter?

Mention some points of difference in the circulation of the blood before and after birth.

Describe the structure of the mammary glands.

Mention some factors which influence the development of the mammary glands.

How is the milk formed in these glands?

Compare the composition of human colostrum and milk.

Compare the composition of human milk and cow's milk.

For answers see Chapter XXVI

What is the normal rate of increase in weight during infancy?

What is the average normal rate of increase in height during infancy and childhood?

What should be the rate in increase of muscular strength during infancy?

What is the state of the bones at birth and during early infancy?

What care is necessary to insure their proper development?

What is the condition of the glands at birth?

Why must starch foods, unless they are very thoroughly cooked, not be given infants?

State the rate at which the skull and brain develop.

Discuss the normal rate at which a child's mental capacities develop.

Why is it necessary for those who have charge of the training of children to know something about the rate of development of a child's capacities?

What is meant by the senescence?

To what are the conditions characteristic of the senescence due?

What is meant by arteriosclerosis?
What is the consequence of arteriosclerosis?
Mention some causes of premature arteriosclerosis.
Why is sleep necessary?
Mention some theories regarding the cause of sleep.
To what are dreams thought to be due?

FOOD VALUES OF A FEW FOOD MATERIALS AND PREPARED FOODS

Food Material	Amount	Weight (gms.)	Protein (gms.)	Fat (gms.)	Carbohydrate (gms.)	Fuel (calories)
Cereals, etc.:						
Arrowroot Gruel arrowroot 1 tbsp. milk 1 cup	1 cup	240	7.52	9.04	25.08	211.[illegible]
Farina	1 serving	100	1.65	0.21	11.45	71.[illegible]
Hominy	1 serving	100	2. 2	0.20	17.80	81.[illegible]
Oatmeal	1 serving	100	2.42	1.45	11.76	69.[illegible]
Rice	1 serving	100	2.80	0.10	24.40	109.[illegible]
Wheat Germ	1 serving	100	1.79	0.34	12.92	81.[illegible]
Desserts:						
Baked Custard egg 1 milk ¾ cup sugar 2 tbsp.	1 serving	245	12.34	12.03	8.61	192.[illegible]
Bread Pudding bread 1 cup egg 1 milk 1 cup sugar ½ cup raisins ¼ cup	1 serving	105	5.52	4.79	38.48	219.[illegible]
Ice Cream, plain cream ½ cup milk ¼ cup sugar 1 tbsp.	1 serving	195	3.90	21.69	19.23	287.[illegible]
Orange Jelly gelatin 1 tsp. lemon juice 1 tbsp. orange juice ½ cup sugar 2 tbsp.	1 serving	175	2.6		44.2	187
Fluids:						
Beef Soup	½ cup	120	5.28	0.48	1.32	30.
Cocoa cocoa 2 tsp. milk ¾ cup sugar 2 tsp.	1 cup	240	7.64	9.50	21.98	204.

Food Material	Amount	Weight (gms).	Protein (gms.)	Fat (gms.)	Carbohydrate (gms.)	Fuel Value (calories)
Fluids:						
Cream, medium	2+tbsp.	40	1.48	10.28	1.41	104.1
Cream of Pea Soup	1 serving		8.20	14.99	16.46	236.55
Butter 2 tsp.						
Flour 2 tsp.						
milk ¾ cup						
peas ½ cup						
Egg Nog	1 glass		12.34	12.03	23.46	302.07
egg 1						
milk ¾ cup						
sugar 1 tbsp.						
whiskey 15 cc.						
Milk	1 cup	240	7.52	9.04	11.28	156.8
Orange Albumin	1 glass	240	3.48	0.06	22.78	105.5
egg white 1						
sugar 1 tbsp.						
orange juice ¼ cup						
lemon juice 1 tbsp.						
Fish, etc.:						
Bluefish	1 serving	100	25.90	4.50		144.10
Mackerel	1 serving	70	11.73	4.84	2.62	100.96
Salmon	1 serving	100	19.65	10.21	5.36	191.93
Trout—brook	1 serving	50	10.57	1.17	.62	55.29
Clams, long	6	150	12.90	1.5	3.00	77.1
Oysters	6	85	5.27	1.02	3.15	42.86
Fruits:						
Apple	1 average	150	0.45	0.45	16.20	70.65
Banana	1 average	194	1.55	0.78	27.74	124.18
Grapes	1 bunch	150	1.50	1.80	21.60	109.60
Orange	1 average	250	1.50	0.25	21.25	93.25
Strawberries	1 serving	100	1.00	.60	7.40	39.00
Prunes, with juice	4 large	200	1.00	0.20	44.60	184.20
Meats:						
Bacon	1 serving	30	2.98	18.37		177.2
Beef Steak—porterhouse	1 serving	120	21.64	20.28		269.08
Chicken	1 slice	100	32.10	4.40	2.10	176.40
Lamb Chop	1	100	21.70	29.90		345.9
Miscellaneous:						
Bread, white—baker's	1 slice	30	2.76	0.39	15.93	78.27
Bread, graham	1 slice	37	3.29	.67	19.28	96.31
Butter	1 ball	15	0.15	12.75		115.35
Cheese, American	1 cu. in.	20	5.70	7.18	.06	87.66
Cheese, cream	1 cu. in.	20	5.18	6.74	.48	83.30
Egg	1	50	6.70	5.25		74.05
Egg, white	1	25	3.3			13.2

Food Material	Amount	Weight (gms.)	Protein (gms.)	Fat (gms.)	Carbohydrate (gms.)	Fuel Value
Miscellaneous—continued:						
Egg, yolk	1	13	2.1	4.5		46
Lactose	1½ tbsp.	30			15.0	60
Sugar	1 tbsp.	30			15.0	60
Whiskey	15 cc.					50
Vegetables:						
Asparagus, fresh	1 serving	120	2.04	0.24	3.72	25
Beans, lima	1 serving	120	4.08	0. 8	25.04	139
Beans, string	1 serving	60	0.48	0.66	1.14	12
Cauliflower	1 serving	120	1.08	0.12	.48	
Celery, raw	4 stalks	60	0.62	0.06	1.86	10
Peas, green	1 serving	90	5.94	0.42	14.37	84
Potatoes, baked	1	130	3.77	0.20	32.07	145
Spinach	1 serving	100	2.10	4.10	2.60	55
Tomatoes, raw	1 average	200	2.40	0.40	8.00	45

NOTE: This Table of Food Values was compiled by Miss Alice C. Keith.

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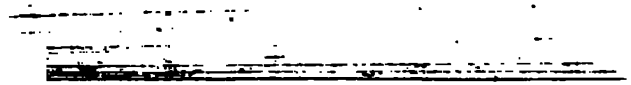

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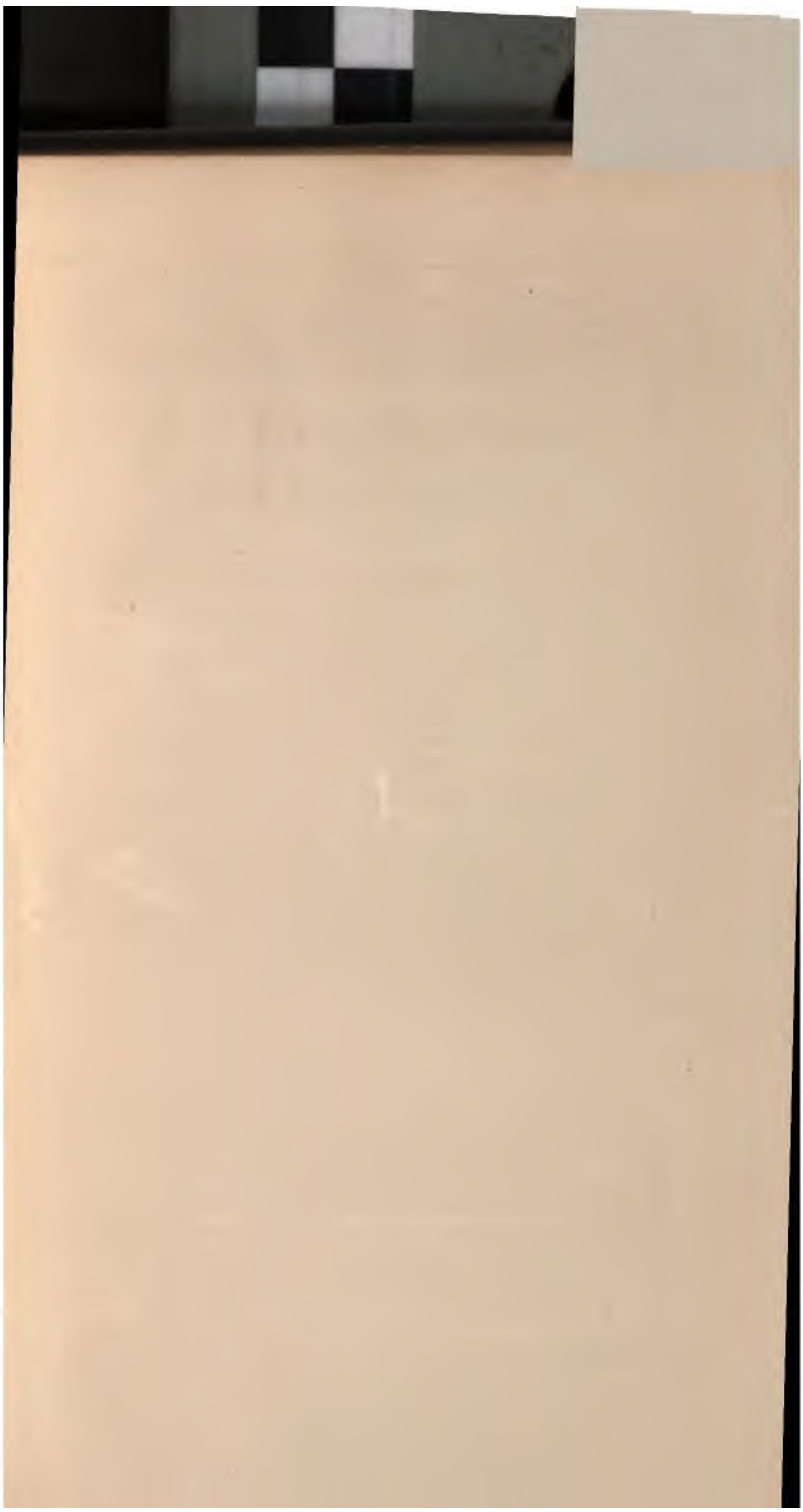

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